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FINAL REPORT

COST BENEFIT ANALYSIS OF THE TRANSFER OF NASA REMOTE SENSING TECHNOLOGY TO THE STATE OF GEORGIA

BY

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ENGINEERING EXPERIMENT STATION

Georgia Institute of Technology

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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FOREWORD

The "Cost Benefit Analysis of the Transfer of NASA Remote Sensing Technology to the State of Georgia" under Contract NAS9-15283 was conducted by the Engineering Experiment Station (EES) at Georgia Tech. The Program was administered under Georgia Tech Project A-1964 by the Systems Technology Branch within the Systems Engineering Division.

This report describes the work performed during the period March 1977 through October 1977. The program was managed by the NASA Earth Resources Laboratory at Slidell, Louisiana. The NASA Technical Monitor was Dr. Armond Joyce.

The Georgia Tech Project Director was Mr. Robert P. Zimmer and the project team was comprised of the following key personnel and areas of contribution:

R. David Wilkins	Associate Project Director and Systems Analyst
David L. Kelly	Economist and Systems Analyst
D. M. Brown	Systems Analyst
Nickolas L. Faust	Remote Sensing Technology and Users
Lawrie Jordan	Remote Sensing Applications in Georgia

Special acknowledgement is due Mr. Bruce Rado, State of Georgia Department of Natural Resources, who served as the liaison with the various state users and whose timely guidance and assistance were so important in accomplishing the program objectives.

ABSTRACT

The objective of this program was to determine the first-order costs and benefits of the transfer of NASA remote sensing technology to the State of Georgia via the Regional Applications Program. The approach used in carrying out the analysis was to identify the benefits in quantifiable and qualitative terms and to value the benefits utilizing the equivalent of a cost-effective analysis. In this approach, the benefits were taken to be derived from the equivalent of Landsat data products. These could be obtained from the Landsat Data System (LDS) or from a Best Alternative Equally Effective Data System (BAEEDS). These two systems were compared in a comparison of the baseline scenario (without Landsat) and the alternative scenario (with Landsat). The scenarios were generally defined to reflect the anticipated acquisition schedule for products for future time periods. The benefits of the technology transferred were then evaluated with a focus on the differences between the two scenarios. Important parameters in the analysis were identified and sensitivity analyses were performed to determine the sensitivity of the analytic results to variations of parameter values about the nominal estimates.

Based on a survey the users within Georgia were categorized into three principal functions areas: permitting, enforcement, and planning. The perceived benefits were characterized in terms of these three functions. This functional approach for describing benefits permit an extrapolation to a regional basis.

Nominal case, one-year costs were established for the Landsat Data System and the Best Alternate Equally Effective Data System (see Table 4-2). The calculated Net Present Value (NPV) of the transfer of technology to Georgia was about \$9.5 million, with a range of \$6.5 to \$12.5 million corresponding to reasonable lower and upper bounds of the parameter estimates. The parameters to which the NPV was most sensitive were the discount rate, photo acquisition, and photo digitization.

Another issue that was investigated was concerned with providing insight into the impact of a budget constraint on a land cover data system. In particular, the comparable frequencies of information update with and without Landsat was investigated. It was determined that, for a constraint budget, Landsat could provide digitized land cover information roughly seven times more frequently than otherwise could be obtained.

It should be pointed out that the time of this study, the State of Georgia had not completed its training program to utilize Landsat data. With operational experience established, a second interaction of the benefits valuation would further establish the future benefits of Landsat technology and provide a further validation of the methodology that was used in this investigation.

This report presents material in five sections. The first section gives the background discussion of the Landsat data system itself and the user community within the State of Georgia. An overview of cost benefit analysis is presented wherein the essential scenario comparison and evaluation notions are discussed at some length. The second section of the report addresses itself to specific candidate approaches which were considered in conducting this study. The alternative approaches for performing cost benefit analysis are presented and the choice of the selected approach is discussed. The third portion of the report focuses on the scenario developed for use in the analysis. This development includes the user survey, results of the survey, classification of the Landsat data system benefits, and developing specific scenarios for comparison. A quantitative analysis of the scenarios utilizing the baseline system and the Landsat data system is made in Section 4. Section 5 presents sensitivity analyses. The conclusions and recommendations drawn from the analysis are presented in Section 6.

TABLE OF CONTENTS

<u>SECTION</u>		<u>PAGE</u>
1	PROBLEM DEFINITION.....	1
	1.1 Landsat.....	1
	1.2 The Technology Transfer.....	5
	1.3 Analysis Goals.....	8
2	METHODOLOGY DEVELOPMENT.....	11
	2.1 Overview of Cost Benefit Analysis.....	11
	2.2 Alternate Approaches.....	15
	2.3 Selected Analysis Technique.....	17
	2.3.1 Rationale.....	17
	2.3.2 Decision Structure.....	18
	2.3.3 Net Present Value.....	21
3	SCENARIO DEVELOPMENT.....	23
	3.1 Introduction.....	23
	3.2 User Survey.....	24
	3.3 Data Products.....	30
	3.4 Selected Scenarios for Analyses.....	39
	3.5 Benefit Categories.....	44
	3.5.1 Introduction.....	44
	3.5.2 The Planning Function.....	46
	3.5.3 The Permitting Function.....	46
	3.5.4 The Monitoring Function.....	47
4	QUANTITATIVE ANALYSIS.....	51
	4.1 Scenario Assumptions.....	51
	4.2 Important Parameters.....	53
	4.3 Results.....	57
5	SENSITIVITY ANALYSIS.....	62
	5.1 Parameters.....	62
	5.2 Calculated Results.....	64
	5.3 The Effects of Less Frequent Land Cover Information.....	67

TABLE OF CONTENTS (Cont'd.)

<u>SECTION</u>		<u>PAGE</u>
6	CONCLUSIONS AND RECOMMENDATIONS.....	76
	6.1 Conclusions.....	76
	6.2 Recommendations.....	77
APPENDICES -		
I	GEORGIA NATURAL RESOURCES INFORMATION SYSTEM.....	79
II.	IMPACTS OF REMOTE SENSING TECHNOLOGY ON USER OBJECTIVE.....	84
III.	MODELS OF THE BENEFITS DERIVED FROM THE LANDSAT DATA SYSTEM.....	94
IV.	CBA COMPUTER PROGRAM AND NOMINAL CASE INPUTS.....	128

LIST OF FIGURES

<u>FIGURE NO.</u>	<u>TITLE</u>	<u>PAGE</u>
1-1	Elements of the Technology Transfer Process....	6
1-2	Outline of the Study.....	10
2-1	CBA Focuses on Differences.....	12
3-1	LDS Benefit Classification.....	29
3-2	Approach to Developing Scenarios.....	43
4-1	Overview of the Cost Analysis.....	52
4-2	Nominal Case Annual Cost of Data Systems vs. Time (1977\$).....	58
5-1	Net Present Value vs. Discount Rate.....	65
5-2	Net Present Value vs. Photo Digitization Cost..	66
5-3	Net Present Value vs. Photo Acquisition Cost...	68
5-4	Net Present Value vs. Photo Interpretation Cost.....	69
5-5	Net Present Value vs. Landsat Tape Cost.....	70
5-6	Net Present Value vs. Landsat Processing Cost..	71
5-7	Prior to 1981 Quarterly Data Products from LDS vs. Data Products Every T Quarters Using High Altitude Photography.....	74
5-8	1981 and After Quarterly Data Products from LDS vs. Data Products Every T Quarters Using High Altitude Photography.....	75

LIST OF TABLES

<u>TABLE NO.</u>	<u>TITLE</u>	<u>PAGE</u>
1.1	Some Anticipated Applications of Land Cover Information Derived From Landsat Multi-Spectral (MSS) Scanner Digital Data.....	3
2.1	Problem Identification, Cost and Benefit Valuation.....	14
2.2	The Equal Effectiveness Decision.....	20
3.1	Initial List of Potential Landsat Users Within the State of Georgia.....	25
3.2	Procedure for Interaction with Users.....	27
3.3	Summary of Data Requirements.....	31
3.4	Land Cover Categories of Interest.....	32
3.5	User Requirements for Land Cover.....	37
3.6	Production and Distribution Schedule for Landsat Data Products.....	40
3.7	Selected Scenarios.....	42
3.8	Categorization of Users by Function.....	45
4.1	Cost Parameter Data Sources.....	55
4.2	Nominal Case One-Year Costs (Acquisition and Processing 4 times per Year).....	56
4.3	Upper and Lower Bounds on LDS Value.....	59
5.1	Sensitivity Analyses.....	63
5.2	Cost Elasticities of Landsat Value.....	72

LIST OF ABBREVIATIONS

APDC's	Area Planning and Development Commissions
AS	Alternative System
BAEEDS	Best Alternative Equally Effective Data System
BS	Baseline System
CBA	Cost-Benefit Analysis
CEA	Cost-Effectiveness Analysis
CCT	Computable Computer Tape
E	Environment
ERDAS	Earth Resources Data Analysis System
ERTS	Earth Resources Technology Satellite
GNRIS	Georgia Natural Resources Information System
LANDSAT	Land Satellite Program
LDS	Landsat Data System
MSS	Multispectral Scanner
NRST	NASA Remote Sensing Technology
RBV	Return Beam Vidicom
TOTP	Transfer of Technology Program
WQMU	Water Quality Management Units
WPB	Water Protection Branch

SECTION 1

PROBLEM DEFINITION

1.1 Landsat

In order to evaluate its remote sensing research programs, the National Aeronautics and Space Administration (NASA) is interested in analyzing ways in which its research is being effectively applied to promote public interests. As a practical matter, NASA actively supports the transfer of its technology to both private and public sectors. This support is intended to reduce financial risk associated with start-up operations of a new technology and to demonstrate any new capabilities afforded by the technology. Advantages derived from NASA's remote sensing technology, measured in terms of its actual applications, are typically observable only many years after the initial research has begun. Prior to this, NASA's research must be guided largely by best available estimates of its potential benefits.

NASA's remote sensing and satellite technologies have been combined in the Land Satellite Program (Landsat, formerly Earth Resources Technology Satellite or ERTS). There are presently two Landsat satellites in synchronous polar orbits constantly surveying the earth's surface. They are intended to provide a variety of users with up-to-date earth-surface data on a wide-area basis. Landsat-1 was launched in July, 1972, and Landsat-2 in January, 1975.

The satellites carry identical dual imaging sensor systems. One is the Return Beam Vidicon (RBV), a multispectral television system with three frame-format television cameras. The other is the Multispectral Scanner (MSS), a four-channel system that continuously scans the surface transverse to the orbital path; the four channels measure reflected energy in two wavelength bands of the visible light spectrum (.5 to .6 and .6 to .7 microns) and in two wavelength bands of the infrared (.7 to .8 and .8 to 1.1 microns).

By mid-1975, over half a million 185 x 185-kilometer frames of imagery had been made available to the public (the 48 contiguous United

States can be covered in 570 frames, the State of Georgia in 14 frames counting all frames that touch Georgia). The instantaneous field of view of the MSS, i.e., the smallest picture element covers about 1.1 acre. Data received from the satellites is also recorded on computer tape and can then be used to produce a number of data products. The digital data on these tapes has been demonstrated to be useful for mapping and monitoring changes in agriculture, forest resources, water resources, geology, marine and marshland resources, land use, wildlife habitats, environmental quality, and other areas. Some work has been done, and much more is anticipated, in the use of data base overlay techniques incorporating land cover, soils, climatological, topographical, and/or other data. Example applications of the MSS digital data and of the data base overlay (modeling) products are shown in Table 1-1. While Landsat represents only one of the available sources of land cover data, its particular attractiveness lies chiefly in its being a relatively inexpensive information source providing wide-area coverage, frequent land cover data in a computer compatible form.

The continued availability of this data source will be assured for the near term future with the launch of Landsat-C (1978) and Landsat-D (1981). Landsat-C will have an expanded sensing capability in the form of an additional spectral band in the thermal infrared region; rather than sensing points of reflected light, this band will sense heat emittance from the earth's surface. This should enable better classification capability (more accurate and higher level of discrimination among land cover categories) as well as the ability to detect thermal discharges in water bodies. Landsat-D will have six spectral bands and an improved resolution (30m instantaneous field-of-view, about 1/4 of an acre).

The Landsat program was initiated as a research program and the operational capabilities were designed accordingly. Applications of the Landsat data are still typically in early stages of development with private and public users devising and documenting its uses in the management of earth resources and the solution of resource problems. That is, the capability was developed and demonstrated on an experimental basis first; the development of applications for an ongoing operational capability followed.

TABLE 1 1. SOME ANTICIPATED APPLICATIONS OF LAND COVER INFORMATION
DERIVED FROM LANDSAT MULTI-SPECTRAL SCANNER (MSS) DIGITAL DATA*

1. Estimation of an upcoming harvest for major crops as basis for decisions by local agro-industry, e.g., storage, determining appropriate processing equipment, transportation arrangements, etc.
2. Baseline information that would aid county agriculture extension agents, county foresters, wildlife managers, regional planners, etc., in their routine work.
3. Assessment of overall agricultural, grazing, and forest potential of a region, and subsequent use in decision-making, e.g., reservation of prime agricultural land, Rural Development Act plans, etc.
4. Assessment of overall wildlife habitat potential, and the acquisition of or leasing of areas to be managed for wildlife.
5. Baseline information for the management of specified wildlife management areas for specific types of wildlife, e.g., whitetail deer, wood duck, etc.
6. Assessment of erosion hazard and subsequent use for watershed management, EPA Section 208 programs, Conservation Needs Inventory, Small Watershed Act, River Basin planning, etc.
7. Baseline information to establish reforestation needs or other conservation practices for soil erosion control.
8. Baseline information for coastal zone management, e.g., salinity regime and salt water intrusion, marsh productivity of marine life, shoreline measurement, shoreline erosion and accretion, corridor location, general economic development planning, etc.
9. Information for site selection, e.g., public campground/recreation sites, industrial sites, solid waste disposal, etc.
10. Information on rate, type, and location of land use change for urban/regional planning, impounded water surveys, etc.

* This is a representative list of natural resource applications using Landsat for various states.

TABLE 1.1. SOME ANTICIPATED APPLICATIONS OF LAND COVER INFORMATION
DERIVED FROM LANDSAT MULTI-SPECTRAL SCANNER (MSS) DIGITAL DATA (Cont'd).

-
11. Specialized inventories, e.g., area and location of extractive (surface mining) activities, impounded water, forest volume inventory, etc.
 12. Regional environment impact assessment and monitoring, e.g., areas with concentrated surface mining/energy related activities.
 13. Insect/disease infestation assessment and control, e.g., fusiform rust risk rating in pine/oak areas, Southern Pine Beetle damage assessment.
 14. Land capability determination for tax assessment programs.
 15. Surface mine rehabilitation monitoring (dependent on thematic mapper programmed for 1981).
 16. Land resource planning.
-

1.2 The Technology Transfer

The State of Georgia, along with NASA, is currently involved in the transfer of Landsat digital processing technology to what is tentatively to become the Georgia Natural Resources Information System (GNRIS), a state-integrated computerized data base. The Transfer of Technology Program was initiated in the summer of 1975, and regular processing of Landsat data for the entire state began in the fall of 1977.

Figure 1.1 depicts the process associated with the technology transfer system being considered in this study. The process can be described in terms of three essential elements. The Landsat satellite collects data from its sensors and transmits this data to a ground receiving station where it is preprocessed to produce raw digital data on computer compatible tapes (CCT's). The raw data on CCT's is processed with an Earth Resources Data Analysis System (ERDAS) and transformed into land cover data products. These products are then distributed to the user community within the State of Georgia.

The ERDAS system is composed of various computer hardware elements which have the following general functions. ERDAS takes the raw data and performs a rectification of the data wherein distortion deriving from orientation of the instruments relative to the earth's surface is eliminated. The second process accomplished by ERDAS system is geo-referencing wherein the raw data is identified as particular coordinates of the surface of the earth. The third major function performed by the ERDAS system is classification of land cover. This process entails the comparison of the signature contained in the raw Landsat data with land cover and known locations. The final process accomplished by the ERDAS system is in the transformation of the rectified, geo-referenced, classified information into final data products. The data products are in the form of tabulated land cover statistics and land cover maps or a video display of the land cover classification.

The user community within Georgia is comprised of various state agencies and federal agencies with charters to provide specific services. The

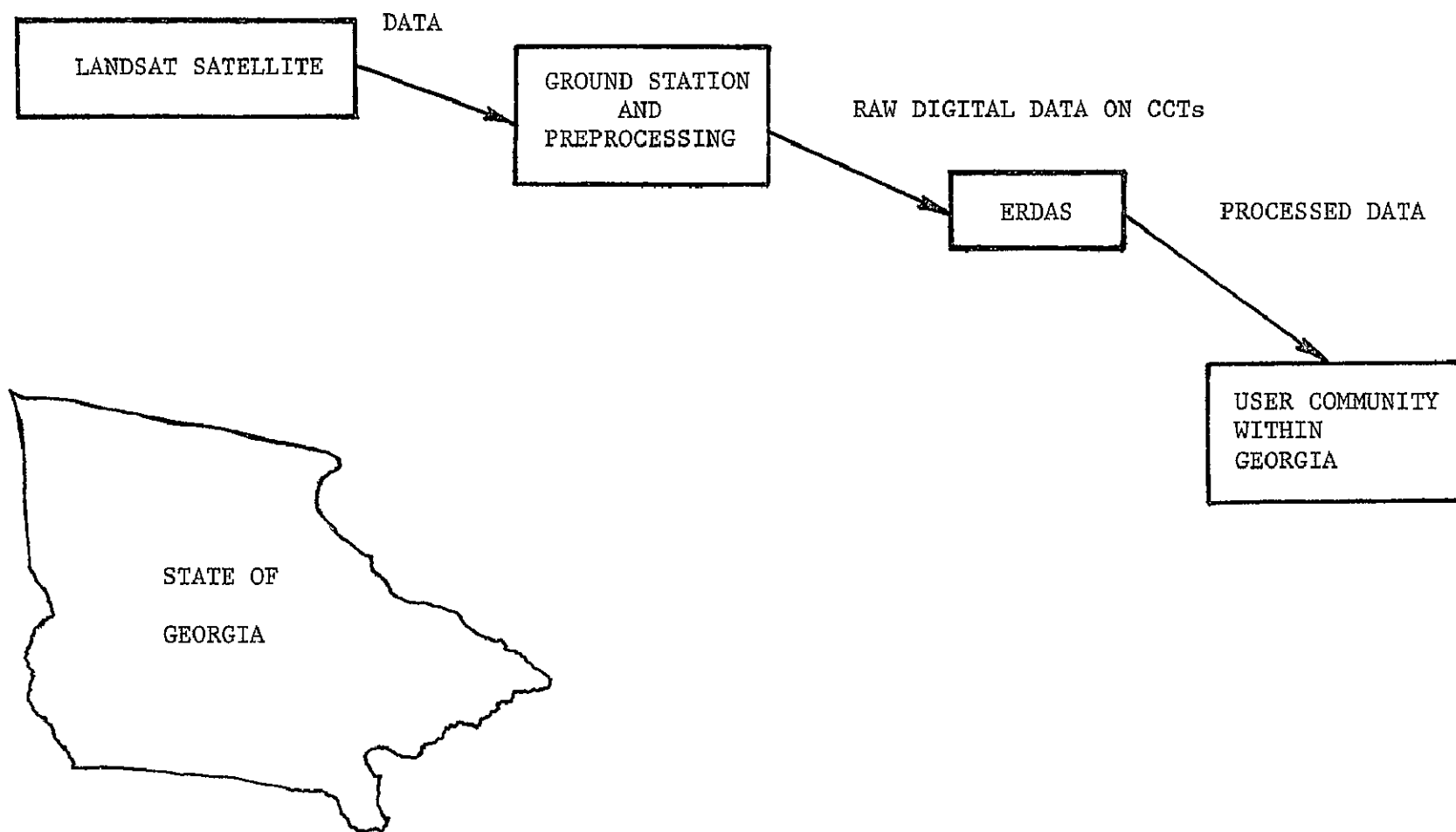


Figure 1-1. Elements of the Technology Transfer Process

8. The United States Army Corps of Engineers

Among the many responsibilities of the Corps, the ones which relate importantly to landcover information are their charters that regulate what land can be used for dredge and fill activities.

The first step of the program, Problem Identification, has been presented in this section. The elements addressed included aspects of the Landsat data system itself and the user community within the state of Georgia. A general discussion of cost benefit analysis will be presented in the next section wherein essential scenario comparison and evaluation notions will be developed. The next section will also address specific candidate approaches which were considered for conducting the study. The alternatives available in performing cost benefit analysis will be presented and the choice of the adopted approach will be discussed. The detailed methodology used in conducting the analysis will be presented in Section 3. The Scenario Development survey includes the user survey, the results of the survey, the amalgamation of the Landsat data system benefits, and the specific scenarios for comparison. Section 4 gives the quantitative analysis and a detailed description of first-order benefits that were identified. The fifth and sixth sections of the report contains a sensitivity analyses, summarizes the results of the study effort and presents conclusions and recommendations drawn from the analysis.

1.3 Analysis Goals

The objective of the study is to determine the first-order cost and benefits of the transfer of NASA remote sensing technology to the State of Georgia via the Regional Applications Program. The emphasis in the study is on the first-order effects of the remote sensing technology which is transferred to the state. That is, the effects which are identifiable in the first sphere of influence of a transfer process or on the first level of cause and effect relationships that can be associated with the Landsat project. And, in particular, emphasis is on first-order effects which are significant in their implication.

community anticipated to use Landsat-derived data is comprised of essentially eight users. A brief statement about each is given below.

1. The Department of Natural Resources, Environmental Protection Division, Land Protection Branch

This state agency is responsible for regulating activities, for permitting various surface mines, for permitting landfills and sanitary landfills, and for periodic inspection of surface activities.

2. The Department of Natural Resources, Environmental Protection Division, Water Protection Branch

Also a state agency, the Water Protection Branch has a responsibility for planning and controlling non-point source water pollution. Most of this responsibility derives from the legislation familiar in 208 plans.

3. Georgia Forest Research Council and the Georgia Forestry Commission

Together these agencies perform forest inventories, have responsibility for various aspects of state forest management and guide research efforts within the forestry area.

4. The United States Department of Agriculture Soils Conservation Service

The general area of interest to the conservation service lies in control of soil erosion and depletion and also in the area of advancing soil productivity.

5. Area Planning and Development Commission

Eighteen such commissions exist in the State of Georgia and are responsible for regional land use planning. The kinds of issues the planning and development commissions engage in are project studies for water systems, fire districting, and support public facilities surrounding economic developments for the locale.

6. The United States Department of Agriculture Forest Service

The Forest Service has responsibility for the protection and proper utilization of the nation's forest as a whole, specifically of interest for this study are the forests of the State of Georgia.

7. The Department of Natural Resources, Game and Fish Division

This state agency has the primary responsibility for wildlife habitat management. Their activities involve protecting endangered species, regulating wildlife populations through hunting season controls and through the establishment of various wildlife preserves and sanctuaries.

Motivation for the cost-benefit analysis of the transfer of remote sensing technology to the State of Georgia lies in the fact that Landsat data have many potential uses and users, each of which may be associated with different benefits. Overall summary characteristics can be stated in terms of decisions associated with the use of land cover information from Landsat. These decisions may be better decisions than heretofore had been possible. Or the decisions may reflect potentially the same decision alternatives, but the same decision is made at a lower cost. A third possibility not explicitly considered in the study is that new and different types of decisions may now lend themselves to consideration. Such new types of decisions might be possible after the users have had extensive experience with Landsat-derived land cover data.

An outline of the steps used in this investigation is shown in Figure 1-2. The six steps are the following. (1) The problem was identified and the nature of the system being studied and analyzed was defined. (2) Candidate approaches for conducting the analysis were identified. (3) An approach most appropriate to the specific study was selected. The availability of data, and peculiarities about the problem itself, and the time and resources available for conducting the study bear on the selection of the candidate approach. (4) After the preferred overall approach to be followed was selected, a detailed methodology was developed for conducting the actual analysis. (5) The methodology was applied in the fifth step of the study wherein the user community and the particulars of the system costs were subjected to the detailed study. The sixth step was the presentation of the results.

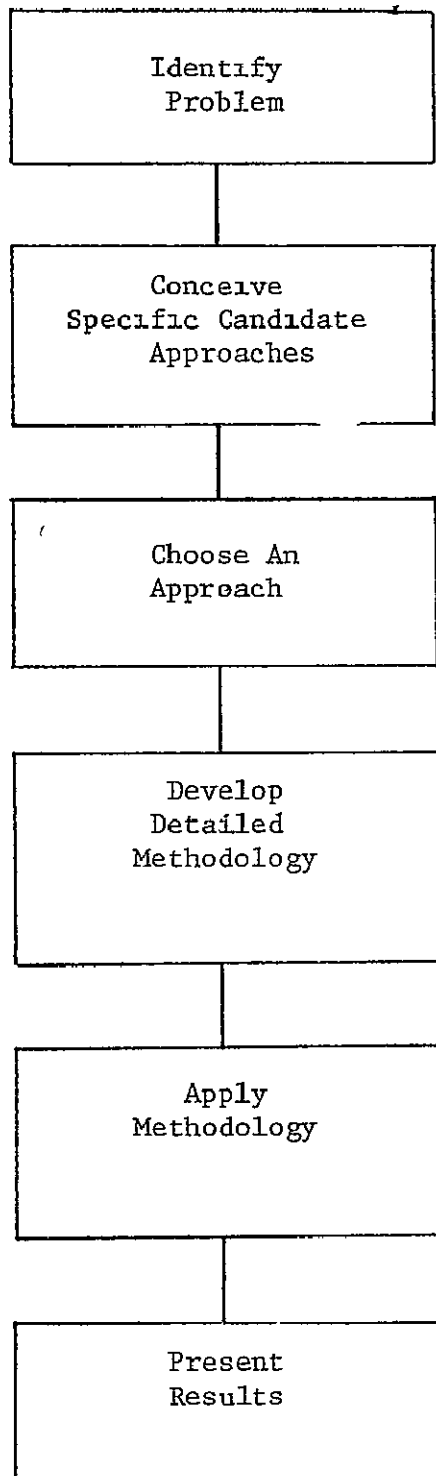


Figure 1-2. Outline of the Study

SECTION 2

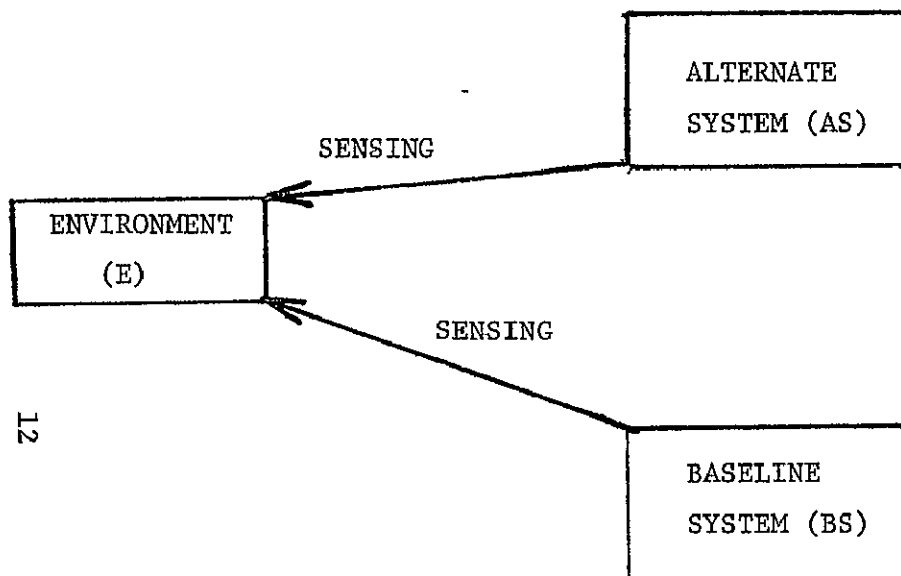
METHODOLOGY DEVELOPMENT

2.1 Overview of Cost Benefit Analysis

In general, a cost benefit analysis may be considered to consist of six basic steps: (1) definition of the project to be evaluated, (2) identification and categorization of significant costs and benefits associated with the project, (3) quantification of both the costs and benefits realized from the project where quantification and valuation are possible, (4) performance of an appropriate economic analysis to determine the net economic value of the project, (5) performance of sensitivity analyses, and (6) consolidation and presentation of results in a clear and useful form.

Some features of cost benefit analysis warrant particular mention. Cost benefit analysis focuses on differences as illustrated in Figure 2-1. The block labeled "environment" is associated with either a baseline system or an alternate system. Typically, the baseline system is the status quo system which is taken as the current system that, if there were no alternative, would remain in effect. The alternate system is the proposed project or investment being considered by the decision maker. For the baseline system, a set of costs typically will be incurred either by the system itself or by those external to the system, but contained in the environment. Similarly, for the baseline system a set of benefits can be identified which are also realized by either the system itself or the environment. These costs and benefits are compared to the corresponding elements associated with the alternative system. This comparison is usually made by computing the net benefit, or benefits minus costs, of the alternative system and the net benefit for the baseline system. The differences in the net benefits between the alternative and baseline systems is a dollar measurement of the net value of the alternative system.

One aspect of cost benefit studies which usually complicates the analytic effort is the evaluation process. Table 2.1 is a matrix overview and evaluation process. The impacts of a project in terms of cost and



COSTS (INCURRED BY AS AND E)
 BENEFITS (REALIZED BY AS AND E)

COMPARED WITH

COSTS (INCURRED BY BS AND E)
 BENEFITS (REALIZED BY BS AND E)

NET VALUE OF THE ALTERNATIVE SYSTEM IS THE DIFFERENCE

$$[B(AS/E) - C(AS/E)] - [B(BS/E) - C(BS/E)]$$

Figure 2-1. CBA Focuses on Differences

benefits can be categorized in one of the four cells shown in Table 2.1 . Generally a project will have some costs and benefits in all of the cells. In each cell, it can be noted the ease with which the valuation can be conducted. With reference to the columns in Table 2.1, the first column relates to cost and benefits which are distributed broadly across a large population. For broad distribution, the effects are marginal on each individual within the population. The second column shown in the table relates to concentrated effects deriving from some project. Relative to population, such types of effects are felt by very few individuals, but the impact on these individuals may be extremely large. With reference to the rows in Table 2.1, the rows are used to distinguish cost and benefits in terms of the types of goods and services that are associated with the costs and the benefits. The first row corresponds to those goods and services which are amenable to some restrictions on their distribution. For this type of good or service some market typically exists wherein voluntary exchanges among individuals can take place. The second row corresponds to other consumables. This term is used to describe all non-market goods and services and conditions which are generally indicative of some state of social well-being. The kinds of goods and services included in this category would be public roads, patriotism, brotherhood, security, and the like. These other consumables and non-market goods, typically are not such that their distribution can be restricted. In fact, no market usually exists for such goods. Thus, the table gives a two-dimensional categorization of costs and benefits. The first cell in the matrix corresponds to the combination of goods and services which are distributed across a broad population so that the effects are marginal on the individuals in the population and their costs and benefits which are indicative of market goods and services. Costs and benefits which fall into this category can be valued in terms of some observable market price. The valuation process may reflect the actual market price prevailing at a point in time or some adjustments in that market price depending on the character of the market, that is, depending on the extent to which there is free competition in that market.

TABLE 2.1
PROBLEM IDENTIFICATION
COST AND BENEFIT VALUATION

Type of Goods	Distributed effects: relative to those affected (society as a whole) the effects are marginal.	Concentrated effects: relative to those affected (selected individuals) the effects are large.
Market goods and services (goods and services amenable to restricted distribution.	Market price is the basis for valuation (e.g. public health services).	Marginal market price not relevant. No objective basis for valuation (e.g. confiscation of private residences).
Other "Consumables" (non-market goods and services and conditions which reflect social well-being.	Where similarities exist, comparison with market goods and services is basis for valuation (e.g. degradation of community water supply).	No objective basis for valuation (e.g. health hazard posed by nearby sanitary landfill).

In the same column is depicted effects of non-market goods and services, that is, column 1, row 2 category. An example of an item which falls into this category is the quality of the community water supply. Such goods and services do not lend themselves to any market price valuation. Typically, there are no similar goods or services for which there is an economic market. There is very little on which to base an objective valuation of the costs or benefits associated with goods or service. In the second column, first row, is the category for concentrated costs and benefits for which there is a market of goods and services. The fact that a market may exist does not in itself constitute a legitimate basis for valuing the goods and service. There are too many intangibles associated with the good or service, and generally these intangibles are, in a sense, overwhelming for the particular individuals affected. Categorized in the final cell of the matrix are the concentrated effects of non-consumable non-market goods. These similarly do not permit any objective valuation of cost and benefits. Table 2.1 is useful in terms of a preliminary assessment as to what form a cost benefit analysis might be expected to take. If a large number of the anticipated costs and benefits identified with a project fall into the upper lefthand cell in Table 2.1, quantifiable benefits and meaningful economic conclusions can be usually achieved. If the bulk of the costs and benefits associated with the project fall into the other three cells in Table 2.1, as is typically the situation in cost benefit analyses, then special care and caution needs to be taken to arrive at useful and meaningful results. In projects which are supported by public agencies, such as the State of Georgia, cost benefit analysis typically allows very little direct economic valuation of the costs and benefits to be addressed. The initial aspects of the user survey indicated that indeed direct evaluation would be limited and this led into an in-depth consideration of the alternate approaches to determine which to use in carrying out this analysis.

2.2 Alternate Approaches

In evaluating Landsat technology, a reasonable approach would be to compare the performance and costs of an inventory system when no Landsat

products are used to its performance and costs when Landsat products are employed. This is the basic approach of cost-benefit analyses (CBA). In general, both the system and costs might be expected to change with the adoption of Landsat data products. If the changes in the inventory system could be expressed in dollar terms, then the fact that both system performance and system cost change would post no difficulty; all the effects of employing Landsat data products, being expressed in the same terms, could readily be combined. CBA's rarely, if ever, exhibit such dimensional homogeneity, but none-the-less generally allow some amount of netting costs from benefits. In such an intermediate case the limited aggregation which is possible often allows the economics of choice among competing alternatives to be clearly established at least ordinally. In the CBA of the Landsat technology transferred to the State of Georgia, Landsat data products are to be used as inputs to the production of public goods and services. Consequently, certain benefits, though identifiable, were not generally measurable in dollars. Not being subject to the objective (though generally imperfect) valuation process of the marketplace, the value of the benefits derived from Landsat data products cannot be estimated directly.

Alternative analysis techniques were considered in performing this cost benefit analysis in view of the objective of this investigation. First, was performing a cost benefit analysis wherein a comparison is made between the Landsat data system and the current means for determining land cover within the State of Georgia. To some extent, second order impacts and nebulous first order benefits could be explicitly included. The major shortcomings of adopting this straightforward approach to cost benefit analysis has already been eluded to in the previous discussion. Such benefits derived from the Landsat data system cannot be quantified with any reasonable level of confidence. The second major shortcoming of this approach is, even for those benefits which might be quantified, very few will be expected to be amenable to objective valuation.

A second alternative approach in performing a cost benefit analysis is to use the analysis to establish bounds on the net present value to the

Landsat data. Such an approach compares the Landsat data system with a data system that produces identical data products. There are two major shortcomings of this bounding approach. First, the identical product data system itself may be far from optimal. If this is the case, the bounds established on the economic value of a Landsat data system would be very loose bounds, and therefore, of doubtful meaning and consequence. A second shortcoming of an identical product data system approach lies in the fact that conceivably, having no land cover data would be preferred to incurring the cost of the identical product data system. If this preference would be true, then the bounds established for the net present value of the Landsat data system would be totally invalid.

The third candidate technique identified for the analysis was to identify and model, where practical, the benefits associated with the Landsat data system data products, and in a parallel effort perform the equivalent of a cost effectiveness analysis. In this approach, Landsat data system is compared with some best alternative equally effective data system (BAEEDS). For this approach to be meaningful, the Landsat data products that are provided to the user community must be necessary and sufficient to satisfy practical user requirements. This necessary and sufficient condition appears to be at least approximately satisfied in actuality because users have already expressed a preference for the Landsat data system over alternatives which might be considered.

2.3 Selected Analysis Technique

2.3.1 Rationale

The technique selected for the analysis was the third one listed above -- identification of the Landsat benefits accompanied by performing the equivalent of a cost effective analysis. The reasons for this selection were as follows. Although the State of Georgia is one of the leaders in utilizing Landsat data, users have not yet had the occasion to receive Landsat data products. Thus, limited data is presently available to quantify certain types of Landsat benefits. Another reason supporting the choice of our approach was that it precludes the necessity of having to make highly subjective dollar valuations of the benefits and costs associated with second order

impacts of the Landsat data system. A third reason supporting the approach is that it suffices to express the system effectiveness in terms of an intermediate system output. In the present case, this intermediate output is the set of data products to be derived from the Landsat data system. These data products are known with a fairly high degree of confidence. This proxy measure of effectiveness is adequate since regardless of the source of any land cover information, any system which produced a specified set of data products would yield the same ultimate utility in benefits. A fourth and very important reason supporting the choice of the cost effectiveness analysis approach is that the user community has already committed resources, money and manpower, to obtaining Landsat data products. Implicitly the user community itself has specified the level of effectiveness that is to be addressed.

2.3.2 Decision Structure

The decision alternatives selected for structure of the problem are such that they are in some sense equally effective in producing some desired results (benefits). Generally, the equal-effectiveness condition implies only that all the competing decision alternatives yield results that meet or exceed some minimal requirements. The implicit assumptions are (1) that a benefit deficit, the amount by which benefits fall short of some minimal requirements, has a large negative value and (2) that a benefit surplus, benefits in excess of the minimal requirements, has no value. Assumption (1) causes any alternative not meeting all benefit requirements to automatically be eliminated from further consideration. Assumption (2) prevents giving preferential treatment to alternatives which may yield results above the levels actually needed, i.e., levels indicated in the minimal requirements. All the alternatives being equally effective (where the sense of equality is that given above), the choice among them can be made solely on the basis of costs or cost savings (benefits). It is often appropriate to let cost dictate the choice only when significant cost differences exist among the alternatives. If only small cost differences exist, de facto differences in benefits may at least subjectively be considered in making the choice. It is this general philosophy incorporating equally effective

decisions, which was used in valuing the transfer of NASA's remote sensing technology to the State of Georgia. This equal effectiveness approach is described in more detail below.

No universally applicable land cover information requirements exist. The government agencies within the State of Georgia have different land cover data needs as would other members in the general community of potential users of Landsat data products. It is therefore impossible to design a single land cover data system which would be just adequate to the needs of all users. The Landsat data products, however, seem to be well suited to most practical applications of land cover data. It is assumed that the products are sufficient to provide the needed levels of user effectiveness for the users to carry out their charters. It can be argued that based on the widespread interest in Landsat data products on the part of users of land cover data, the products are also necessary for the users to achieve the required effectiveness levels. Accepting the premise that over a wide range of users they are both sufficient and necessary, the Landsat data products can be used as a proxy for the required effectiveness of acceptable land cover data systems. Data systems yielding less information than that obtained from the Landsat data system are, by definition, ineffective (less effective than is deemed necessary) in terms of the results that can be produced using that information. Conversely, any information provided by a data system in excess of that contained in Landsat data products has negligible impact on users' operational effectiveness.

The equal-effectiveness concept in assessing the Landsat data system entails comparing the Landsat data system to the best alternative data system which can produce equivalent (or better) data products. The user decision to be considered is outlined in Table 2.2 in terms of the framework of the equal effectiveness decision postulated for a potential user of Landsat data products. To achieve the required level of operational effectiveness, E , the decision maker can choose the Landsat data system and incur a cost C_2 or he may choose the best alternative equally effective data system (BAEEDS) and incur a cost C_1 . As will be seen later, the BAEEDS can be a form of the current system using current technology (the status quo scenario). It should

TABLE 2.2
THE EQUAL EFFECTIVENESS DECISION

	<u>BASELINE</u>	<u>ALTERNATIVE</u>
	Best Alternative Equally Effective Data System	Landsat Data System
Cost	C_1	C_2
Effectiveness	E	E

Choose system which results in Maximum Net Gain (minimum cost)

be noted that the null alternative (no data system) is not available to the decision maker since it would not yield the required level of effectiveness, E.

It is assumed that the actual decision to choose the Landsat data system would be made on the basis of maximum net gain. This implies $(E-C_2) \geq (E-C_1)$ or equivalently $C_1 - C_2 \geq 0$. The value of the Landsat data system can be expressed in terms of the BAEEDS; it is the additional net gain realized by the users being able to choose the Landsat data system rather than having to use the BAEEDS in order for the users to achieve the desired level of effectiveness.

2.3.3 Net Present Value

The above discussion centered on valuing costs and benefits and on alternate decision forms. However, nothing was said as to the most appropriate method to compare costs and benefits that occur at some time in the future. There are several methods that incorporate the time aspect in evaluating alternative investment projects. By name, these are net present value, cut-off period, pay-back period, internal rate of return, annual value, and equity. These have been discussed in a previous Georgia Tech report*. Of the above methods, the net present value technique is considered to be the most appropriate in most applications.

The net present value (NPV) method reduces a stream of costs and benefits to a single number in which costs or benefits which are projected to occur in the future are "discounted." For example, if a project is expected to yield a benefit worth \$100 next year, we might value that \$100 next year, as \$95 today. There are several reasons for discounting and a number of competing arguments as to how the discount rate ought to be determined. These are discussed elsewhere in this work. The formula is

$$NPV = \sum_{t=0}^n \frac{B_t - C_t}{(1+D)^t}$$

* "Benefit-Cost Methodology Study with Example Application to the Use of Wind Generators," R. P. Zimmer, et. al., NASA/Lewis Contract No. NAS3-17827, July 1975.

where C_t is the end of the year dollar value of costs incurred in year t ,

B_t is the end of the year dollar value of benefits realized in year t ,

d is the annual discount rate, and

n is the life of the project in years.

The principal problem associated with using the NPV method is the determination of the appropriate discount rate. However, as we shall see, the consideration of a range of reasonable values is often sufficient in a CBA. Of course, the higher its NPV, the better is a project.

In applying the above to evaluating the Landsat data system, the notion of benefits, B , is considered from two viewpoints. Since the NPV of one project is compared with that of another project, the focus, as mentioned earlier, is on the differences in the projects. If one portion of B is taken to be the dollar value of the effectiveness, E , of a project, then for two projects having equal effectiveness or equal benefits, the dollar value of the effectiveness does not have to be calculated since they would cancel out. B can also be measured in terms of negative costs or cost savings. As shall be seen in the following sections, these are the types of costs and benefits that form the basis for the calculations and sensitivity analyses.

SECTION 3

SCENARIO DEVELOPMENT

3.1 Introduction

As discussed in Section 1, the objective of this program is to determine the first order cost-benefit of the application of remote sensing technology developed by NASA and transferred to the State of Georgia via the Regional Applications Program. This Regional Applications Program is associated with what might be called the Georgia Natural Resources Information System (GNRIS) which is discussed in Appendix I. Insofar as such a system consists of potential users of the remote sensing technology, one of the first steps in carrying out the cost benefit analysis was defining the problem in sufficient detail. Such detail permitted carrying out an analytic design and performing the various model calculations and sensitivity analyses so that the results could be generated within the time frame of the program and can be presented in a format that is suitable for the decision-makers. With respect to the utility of the cost-benefit analysis performed under this program, the "decision-maker" is presumed to be some level of management in the NASA organization. Thus, the basic question that is being addressed is, What is the cost-benefit of "the use of Landsat digital data and computer implemented techniques"?

While the program objective might be stated simply as in the previous question, the actual structure of the cost-benefit problem, which has been discussed somewhat in Section 1, can be stated in terms of choosing between two or more alternatives. What are the alternatives and what are the decision measure(s) and criterion are questions that typically can be answered by looking at the specific objectives of the program. The criterion used for evaluating alternative concepts is the Net Present Value (NPV). The complete structure of the problem then can equivalently be stated in terms of measuring the Net Present Value of the difference between the two alternatives, and these alternatives are simply the baseline scenario and alternative scenario. Emphasis is given toward the calculation of the Net

Present Value of the difference in net benefits between scenarios.

Section 3.4 defines, in more detail, the baseline and alternative scenarios; there the problem can be perceived in terms of the differences in general nature of the baseline and alternative scenarios. It is the remote sensing technology in the alternative scenario as discussed above that is being evaluated relative to the technology in the baseline scenario.

3.2 User Survey

The focus of the interaction with users has been on determining decision methodology and decision impacts. Determination of decision impacts involves consideration of how a decision brings about observed or anticipated results, what the results actually are, why and to whom the results are deemed to be desirable or undesirable.

The list of users that were contacted is given in Table 3.1. These organizational units have been identified by Georgia's Office of Planning and Research as potential user agencies of digitized Landsat information. The overall procedure used for interaction with these users is given in Table 3.2. The initial interview with users served the purpose of (1) introducing the user to the objectives and cost-benefit methodology of the program, (2) developing an understanding of the user as a decision maker, and (3) identifying benefit and cost categories relative to the addition of Landsat to the user's input data. In order for the user to develop a full understanding of the types of information that are being requested, some knowledge of the framework in which the information is to be used is important. In addition, before an evaluation of the potential application of Landsat data to the user's problems can be made, the user must be understood as performing in some decision making role. The next step was to identify sources of information currently available to the user for making his decisions and to determine the effects of additional sources of information, specifically Landsat, on improved decision making.

TABLE 3.1. INITIAL LIST OF POTENTIAL LANDSAT USERS WITHIN
THE STATE OF GEORGIA

<u>Agency</u>	<u>Activity</u>
DNR/EPD/LPB	This is the Surface Mining Land Recovery Program and involves issuing site permits based upon a Mine Land Use Plan as submitted by requestor. A monitoring function is performed to detect violations and nonpermitted operations.
Ga. Forest Research Council	Council sponsors research into areas of protection, enhancement, and utilization of the forest resources.
Ga. Forestry Commission	Commission provides services to woodland owners and the forest industry: fire and disease protection, forest management plans, reforestation, et.al.,
DNR/EPD/LPB	This is the Municipal Permitting Program and involves issuing site permits for sanitary landfills based upon requestor's proposal. A monitoring function is performed to detect violations and nonpermitted operations.
DNR/EPD/WPB	Concern is with non-point sources of water pollution. Overall program is to develop a strategy for management of water resources.
USDA/SCS	Concern is with preventing soil erosion and depletion and with keeping crops in production.
US Army Corps of Engineers	Corps issues permits for dredging and fill operations around major waterways; also develops water impoundment projects.
US Army-Fort Benning Environmental Management Office	Concern is with preparation of Environmental Impact Statements for Benning's projects; also concerned with siting decisions.

TABLE 3.1. INITIAL LIST OF POTENTIAL LANDSAT USERS
 WITHIN THE STATE OF GEORGIA (Cont'd.)

<u>Agency</u>	<u>Activity</u>
DNR/Game & Fish	Concern is with quality, quantity, and distribution of wildlife habitats.
	OPR lends technical assistance and performs applied types of research for other divisions within DNR; OPR generates, analyzes, and prioritizes policy and criterion, and forecasts and assesses impacts of various state sponsored projects.
University of Georgia Agricultural Economics	Concern is with development of policies and food production, distribution methods that ensure maximum yield at minimum cost.
North Ga. APDC	APDC's perform regional development studies, land use plans and projections; they act as liaison between state and county governments.
USDA/FS	Concern is with protection, enhancement, maintenance, and utilization of the nation's forest resources.

Abbreviations:

DNR -- Department of Natural Resources
 EPD -- Environmental Protection Division
 LPB -- Land Protection Board
 OPR -- Office of Planning and Research

USDA -- U.S. Department of Agriculture
 SCS -- Soil Conservation Service
 FS -- Forest Service
 APDC -- Area Planning and Development Commission

TABLE 3.2
PROCEDURE FOR INTERACTION WITH USERS

<u>Step</u>	<u>Activity</u>
1.	Initial interview with user to 1) introduce user to present program and to present to him the cost-benefit methodology to be used on the program, 2) develop an understanding of the user as a decision maker and therefore identifying the types of decisions made, and 3) identify preliminary benefit and cost categories for additional information provided to the user.
2.	User provides Georgia Tech with preliminary information requested.
3.	Second meeting to 1) present to the user an assessment of collected information, 2) identify additional details needed and 3) discuss assumptions relative to the particular user.
4.	User provides Georgia Tech with additional details.
5.	Final meeting for further discussion on assessment/analysis.

Evaluation of these effects required some knowledge of the impacts of the user's decisions and usually resulted in a preliminary identification of cost and benefit categories.

Following the initial interview and after reviewing any material provided by users, a second meeting was set up to present an assessment of material received and information obtained from the user in the initial interview. For each cost and benefit category identified, an attempt was made to quantify the additional benefits (resulting from improved decision making) in dollar terms. Many of the benefits of course are nonquantifiable and are treated separately in the analysis. Finally, a third meeting was required with some users for further discussions and final assessment.

Understanding of the user as a decision maker involves determination of types of decisions required by his program, the impacts of these decisions, his information sources and their respective roles in his decision methodology, and the context within which he carries out his programs. The State of Georgia potential users of NASA remote sensing technology (NRST) were classified into two broad categories as shown in Figure 3-1. The first category involves protecting the public and public resources and the second category involves supporting economic development. Each of these categories may be further sub-divided. Category I includes the functions (1) research and development (planning), (2) issue of permits to allow site specific activities, and (3) implementation and enforcement of land use regulations. Planning impacts budget allocation and investments in long term benefits. Examples are prioritization of items for allocation of funding and deciding when to spend to maintain future benefits while minimizing present cost. The permitting function assures that currently realized benefits will not be endangered, for example, by issuing permits for an environmentally endangering activity. Implementation of monitoring and enforcement results in the detection and correction of activities that have negative benefits. An example of an enforcement activity is monitoring of surface mining sites to insure that permitted operators are abiding by their plan for protection of the environment.

PUBLIC AGENCY FUNCTIONS RELATED TO LANDCOVER

CATEGORY I - Protecting of the public and public resources

1. Program Research and Development (planning).
2. Program Permitting.
3. Program Implementation and Enforcement

CATEGORY II - Supporting Economic Development

1. Foster balanced use of state resources.
2. Enhancing land productivity.
3. Eliminating barriers to regional development (public investments)

Figure 3-1. LDS Benefit Classification

Category II includes (1) an appropriate matching of land use (balanced land use) with land potential, (2) enhancement of land productivity for the given land use and (3) elimination of barriers to regional development. An example of unbalanced land use is the over production of row crops in an area and economy where marketable trees are in short supply. The Georgia Forestry Commission provides for enhancement of land productivity by providing a forest management service to Georgia land owners. Finally the Area Planning and Development Commissions provide for elimination of legal barriers between counties and provide for development on a regional basis.

Classifying users into these functional categories aids in applying a common methodology of cost benefit assessment to similar user types. For each user, effects of additional information such, as Landsat, on his decision making task were determined, and where possible, a dollar value was placed on the impacts of changes in decisions. Brief statements of the user's objectives which may be impacted by the NASA remote sensing technology are given in Appendix II.

3.3 Data Products

To adequately describe the scenarios, it is first necessary to identify the particular data products that each user requires and how often each is needed. The type of data product and frequency of update are dictated by how the data products are to be used. The survey of users indicates data requirements generally relate to different user functions as shown in Table 3.3. The frequencies of update shown in the table are representative of the subset of users who perform each function. It is assumed that between 1977 and 1981 users within the State of Georgia will adapt their data handling procedures to take advantage of a fully digitized data base which is to be potentially available by 1981. In 1981, users are assumed, then, to utilize digitized data products in lieu of the corresponding, but less versatile, statistics they had previously used.

The land cover categories that may be within the detection capabilities of the Landsat sensors are shown in Table 3.4. The categories reflect a tiering into progressively more detailed land cover classifications, Level

TABLE 3.3

SUMMARY OF DATA REQUIREMENTS^(a)

<u>User Function</u>	<u>Frequency of Update</u>	<u>1977 Data Product</u>	<u>1981 Data Product</u> ^(b)
Permitting	Annually	Map	Map Digitized Data
Enforcement	Quarterly	Map (For Wide Area) Statistics (For Site Specific)	Map Digitized Data
Planning ^(c)	Quarterly	Map Statistics	Map Digitized Data
Balanced Resource	Annually	Statistics	Digitized Data
Productivity	Quarterly	Statistics	Digitized Data
Public Investment	Annually	Map (Site Selection) Statistics	Map Digitized Data

(a) Synthesized from survey of Landsat users within the State of Georgia.

(b) Based on a state wide information system employing fully digitized data base and software capability to provide any needed statistics.

(c) Short range planning activities typically depend on seasonal change detection, stratifying land cover classifications based on seasonal appearance, and damage assessment. Quarterly update of information is therefore deemed appropriate.

TABLE 3.4
LAND COVER CATEGORIES OF INTEREST (a,d,e)

Level 1 ^(b)	Level 2	Level 3 ^(c)
Forest - Northern Section	A. Hardwood Dominants	1. Oak Dominant
		2. Oak-Hickory Dominant
		3. River Birch-Sycamore
		4. Tulip Poplar-Beech
	B. Mixed Hardwood/ Softwood	1. Oak-Shortleaf Pine
		2. Oak-Hickory-Pine
		3. Oak-Loblolly Pine
		4. Oak-White Pine-Hemlock
		5. Pine-Mixed Hardwoods
	C. Softwood Dominants	1. Shortleaf Pine Dominant
		2. Virginia Pine Dominant
		3. Loblolly Pine Dominant
		4. Slash Pine Dominant
		5. White Pine-Hemlock
		6. White Pine Dominant
Forest - Northern Section	D. Forest Monoculture	1. Loblolly Pine
		2. Slash Pine
		3. Longleaf Pine
		4. Sand Pine
		5. White Pine
		6. Virginia Pine
Forest - Southern Section	E. Hardwood Dominants	1. Scrub Oaks
		2. Live Oak Dominant
		3. Tulip Poplar-Oak
		4. Tupelo-Mixed Hardwoods
		5. Tupelo-Swamps
	F. Mixed Hardwood/ Softwood	1. Loblolly Pine-Mixed Hard- woods
		2. Slash Pine-Swamp Tupelo
		3. Slash Pine-Swamp Tupelo
		4. Tupelo-Cypress
		5. Oak-Pine
	G. Softwood Dominants	1. Loblolly Pine Dominant
		2. Slash Pine Dominant
		3. Longleaf Pine
		4. Cypress Dominant
		5. Pond Pine

TABLE 3.4
LAND COVER CATEGORIES OF INTEREST (CONT.) (a,d,e)

Level 1 (b)	Level 2	Level 3 (c)
Forest - Southern Section	H. Forest Monoculture . . .	1. Loblolly Pine
		2. Slash Pine
		3. Longleaf Pine
		4. Sand Pine
		5. White Pine
		6. Virginia Pine
Native Grasses and Shrubs	I. Native Grasses	1. Salt Marsh Grasses
		a. Spartina
		b. Juncus
		2. Sawgrass
		3. Wiregrass
		4. Sedges
		5. Heath
		6. Cutgrass
	J. Wet Evergreen Shrubs	1. Ti-ti
		2. Feder
		3. Sapling Bay Species
		4. Myrica/Sweet Bay
		5. Baccharus
	K. Wet Deciduous Shrubs	1. Alder
		2. Tamarix
		3. Sapling Red Maple
		4. Sapling Black Gum
Agriculture	L. Pasture (Grasses Legumes)	1. Fescue
		2. Bermuda
		3. Bahia
		4. Serica
		5. Kudzu
	M. Orchards	1. Apples
		2. Peaches
		3. Pecans
		4. Grapes

TABLE 3.4
LAND COVER CATEGORIES OF INTEREST (CONT.) (a,d,e)

Level 1 (b)	Level 2	Level 3 (c)
Agriculture	N. Crops	1. Cotton
		2. Corn
		3. Soybeans
		4. Peanuts
		5. Small Grains
		6. Tobacco
		7. Sorghum
		8. Truck Crops
	O. Water Type	1. Rivers
		2. Lakes (Greater Than 10 Acres)
		3. Ponds
		4. Ocean
		5. Swamps
		6. Bogs
		7. Sinkholes
		8. Marsh
	P. Exposed Earth	1. Rock Outcrops
		2. Quarries
		3. Surface Mines
		4. Eroded, Non-vegetated Land
Urban and Impervious Surfaces	Q. High Density Urban (Less than 10% Vegetative Cover	5. Spoil Areas
		6. Beaches and Sandbars
	R. Low Density Urban (Greater than 10% Veg. Cover but less than 35% Veg. Cover	1. Asphalt
		2. Concrete
		3. Roof Top
		4. Mixed
	S. Uncategorized	

(a) Compiled from discussion with Landsat users within the State of Georgia.

(b) Higher numbered level of land cover classification reflect progressively higher levels of discrimination.

- (c) Training samples were collected on Level III classifications. It may not be possible using statistical analyses to consistently distinguish among the land cover signatures at this level.
- (d) It is anticipated that all Level II classifications can be separated on Landsat data products. Some Level III classifications may also be identifiable using Landsat instrumentation.
- (e) Classifications A through D correspond to the same land cover as classifications E through H respectively. A given land cover signature differs between North Georgia and South Georgia primarily due to the appreciably different geological characteristics of the two areas.

II being a finer breakdown of Level I and Level III a still finer breakdown of Level II. The ability to distinguish among land cover classifications depends primarily on the sensor's ability to differentiate among the electronic signatures received. It is assumed that all of the Level II categories can be distinguished from one another and at least some of the Level III categories will be distinguishable.

Table 3.5 defines the data products and frequency of update that are expected for each user. The table is compiled by comparing requested land cover classifications with those that are within the established capabilities of the Landsat technology. The data product format and frequency information is taken from Table 3.3.

The information in Table 3.5 must be transformed from a user-by-user tabulation to produce a schedule of the data products that are to be generated. The data products themselves and the cost of the data products will be appropriately distributed among users. This transformation requires making the following assumptions:

- (1) Only those land cover classifications needed to supply current-quarter data products will be processed in each quarter.
- (2) The date for generating annual data products will be during the winter quarter.
- (3) In each quarter, a single map is to be produced showing the land cover classifications for all users requesting a map data product for that quarter.
- (4) Land cover statistics and digitized data products will be supplied to each user for only his requested land cover classifications.
- (5) Where Level III classifications (see Table 3.4) are requested but not possible, data products will be provided for the corresponding Level II classification.
- (6) The classifications to be used in constructing Table 3.6 are all those at Level II plus D(1), I(1a, 1b), N(1,3), P(1 and 2 as a pair), P(4 and 5 as a pair), P(6), and P(3) as a residual classification.

TABLE 3.5
USER REQUIREMENTS FOR LAND COVER^(a)

USER AGENCY	LAND COVER ^(b) CLASSIFICATION	DATA ^(c) PRODUCT		FREQUENCY ^(d) OF UPDATE
		1977	1981	
DNR/EPD/LPB	O(1,2,3),Q,R O,P(1,2,3,4,5)	Map Statistics	Map Digitized Data	Annually Quarterly
GFRG/GFC	A,C,D,G,H B(5),F(1) E(1,2,3,4),O	Map and Statistics	Map and Digitized Data	Quarterly
USDA/FS	A,C,D,G,H B(5),F(1) E(1,2,3,4),O	Digitized Data	Digitized Data	Quarterly
DNR/EPD/WPB	Q,R,P(1,2,5,6), N(2),L,A(1),B,C, E(2,5),F(3),G(1, 2,3,5),D,H,I(1a, 1b),O(1,2,3,5,8)	Map and Statistics	Map and Digitized Data	Quarterly
USDA/SCS	L,M,N(2,3,4,6)	Map and Statistics	Map and Digitized Data	Quarterly
U.S. Army Corps of Engineers	I(1a,1b) O(1,2,3,5,8) P(1,2,4,5,6)	Map and Statistics	Map and Digitized Data	Quarterly
DNR/Game & Fish	I(1a,1b) A(1,2,3,4) E(1,2,3,4,5) B(1,2,3,4,5) F(1,2,3,4,5) C(1,2,3,4,5,6)	Map and Statistics	Map and Digitized Data	Quarterly

TABLE 3.5 (Cont.)
USER REQUIREMENTS FOR LAND COVER^(a)

USER AGENCY	LAND COVER ^(b) CLASSIFICATION	DATA ^(c) PRODUCT		FREQUENCY ^(d) OF UPDATE
		1977	1981	
DNR/Game & Fish (carried over)	G(1,2,3,4,5) O(2,3,5,6,8) Q,R,P(1,2,5,6) L,N	Map and Statistics	Map and Digitized Data	
APDC	A,B,E,F,L,M,N, Q,R,I(1a,1b)	Map and Statistics	Map and Digitized Data	Annually

(a) Synthesized from written proposals for participation in pilot Landsat data products project and from user survey.

(b) Land cover classification codes shown in Table 3.4.

(c) Data products and frequency of update are those specified by users or inferred from Table 3.3 for the specific user functions.

Other Level III classifications or combinations of Level III classifications that may eventually be distinguishable using Landsat sensors have not been used in defining data products since the ability to provide separate information on these land cover classifications has not yet been determined.

(7) The Level III water type classifications are implicitly distinguished by virtue of prior knowledge.

Aggregating user requirements using these assumptions yields nine distinct data products that are to be produced in 1977 during appropriate quarters of the year and eight distinct data products to be produced in 1981. These are shown in Table 3.6.

3.4 Selected Scenarios for Analyses

Most of these agencies presently make use of whatever data sources are currently available at reasonable cost. The information comprising the individual data bases varies considerably in its age, accuracy, and completeness. This condition has motivated current interest in developing a comprehensive, computerized natural resource information system for selected areas within the state. The Landsat data system's digitized data products are perceived as typical of the constituents that might be included in the State's future information system. Data of many types, digitized and referenced to the same coordinate system, would enable numerous kinds of analyses to be made which are presently impossible due to the lack of suitable input data or impractical due to the need to partially process data manually. A compatible and completely digitized data base is the main feature to be sought in an improved future information system. With proper output equipment and software, such an information system could be used to generate a tremendous variety of low cost map products but this capability would be far overshadowed by the enhanced analytic capability it afforded.

The set of conditions assumed to exist in 1981 are that a fully digitized information system will be operational. It is assumed that with possibly some modifications, the processing hardware and software of the LDS

TABLE 3 6
PRODUCTION AND DISTRIBUTION SCHEDULE FOR LANDSAT DATA PRODUCTS

LAND COVER ^(a) CLASSIFICATIONS PROCESSED	FORM OF ^(b) DATA PRODUCT		CLASSIFICATIONS IN THE DATA PRODUCT	QUARTER OF YEAR DATA PRODUCT PRODUCED				SUBSCRIBING USERS	QUARTER(S) DATA PRODUCT ACQUIRED
	1977 to 1980	1981 and after		1	2	3	4		
Set of 21 Classifications A, B, C, D, E, F, G, H, I1a, I1b, L, M, N3, N1245678, O, P3, P6, P12, P45, Q, R	STAT	DIG DATA	O, P12, P3, P45	X	X	X	X	DNR/EPD/LPB	1, 2, 3, 4
	STAT	DIG DATA	A, B, C, D, E, G, H, O	X	X	X	X	GFRC/GFC	1, 2, 3, 4
	STAT	DIG DATA	A, B, C, D, E, G, H, O	X	X	X	X	USDA/FS	1, 2, 3, 4
	STAT	DIG DATA	A, B, C, D, E, F, G, H I1a, I1b, L, N3, N, O, P12, P45, P6, Q, R	X	X	X	X	DNR/EPD/WPB	1, 2, 3, 4
	STAT	DIG DATA	L, M, N3, N1245678,	X	X	X	X	USDA/SCS	1, 2, 3, 4
	STAT	DIG DATA	I1a, I1b, O, P12, P45, P6	X	X	X	X	CORPS OF ENG	1, 2, 3, 4
	STAT	DIG DATA	A, B, C, E, F, G, I1a, I1b, L, N, O, P12, P45, P6, Q, R,	X	X	X	X	DNR/GAME & FISH	1, 2, 3, 4
	STAT	DIG DATA	A, B, E, F, I1a, I1b, L, M, N, Q, R	X				APDC ^(c)	1
	MAP	MAP	A, B, C, D, E, F, G, H, I1a, I1b, L, M, N3, N1245678, O, P6, P12, P45, O, R	X	X	X	X	DNR/EPD/LPB GFRC/GFC DNR/EPD/WPB USDA/SCS	1 1, 2, 3, 4 1, 2, 3, 4 1, 2, 3, 4

- (a) Generally these same land cover classifications must be processed each quarter to meet user community requirements. Note that some such as the N3 (Soybeans) classification cannot be furnished "each quarter" but rather only during the growing season.
- (b) Statistics and digitized data are to be provided to meet the specific requirements of each user. Only a single map is to be produced each quarter, this map will show the required land cover classifications of all users requiring a map product for that particular quarter.
- (c) Four of the 18 APDC's in Georgia have presently indicated an interest in Landsat data products. Subscribing APDC's are to receive land cover classification statistics which relate to their individual geographic areas.

could be used to process digitized data from any source. An essential difference between the 1977 and 1981 scenarios (Table 3.6) is the fact that digitized data products have displaced land cover statistics products

The near term is taken to be 1977 to 1980. The near term value of the LDS during these years is computed based on the assumption that the 1977 data products in Table 3.6 will be largely unchanged during this period.

The long term is defined as a period commencing in 1977 and continuing into the distant future. The long term is composed of the near term, defined above, plus the period beyond 1980. A value of the LDS (expressed in 1977 dollars) for this latter period is computed based on the assumption that the 1981 scenarios in Table 3.7 will be largely unchanged in the foreseeable future beyond 1981. The long term value of the LDS is found by combining the post 1981 value of the LDS with near term value. This segmentation of time in the year 1981 is used to approximate the likely evolutionary process by which the 1977 scenarios gradually change.

Figure 3-2 gives the process used in developing the scenarios to be compared. Basically, the first step was to identify the Landsat data system's capabilities. This is an indication of the most that could be expected of the Landsat data system. Simultaneously, with the information gathered in the user survey a determination was made of the land cover requirements that will be needed in the State of Georgia. Written requests for specific land cover data submitted by each prospective user was used to identify specific land cover classifications that could be provided. These two basis inputs are then used to determine what land cover data products should be produced. These products are in fact those requirements which are both within the capabilities of the Landsat data system and within the desired requirements of the user community. From this set of data products, we defined two scenarios. The baseline is composed of some lowest costs method for obtaining data products and the data products themselves. This scenario can be defined in

TABLE 3.7
SELECTED SCENARIOS

Baseline Scenario

High Altitude Aerial Photography
Manual Photo Interpretation
Land Cover Products (21 Land Cover Classifications)*
 1977 to 1980
 Maps and Statistics
 1981 and Thereafter
 Maps and Digitized Data (10 Acre Cells)

Alternative Scenarios

MSS 4 Channel Data on Tape
ERDAS Processing
Land Cover Products (21 Land Cover Classifications)
 1977 to 1980
 Maps and Statistics
 1981 and Thereafter
 Maps and Digitized Data (10 Acre Cells)

*Note A complete delineation of proposed land cover classifications or categories is given in Table 3.4. Categories A, B, C, and D are no different from E, F, G, H (at Level 2) except as inferred from the geographical position (north Georgia vs. south Georgia). Some people may consider this 4 categories rather than 8. It is expected that all the Level 2 land cover classifications in Table 3.4 will be distinguishable and further, some of the Level 3 classifications will be distinguishable. The twenty-one classifications which are to actually be provided are shown in Table 3.6.

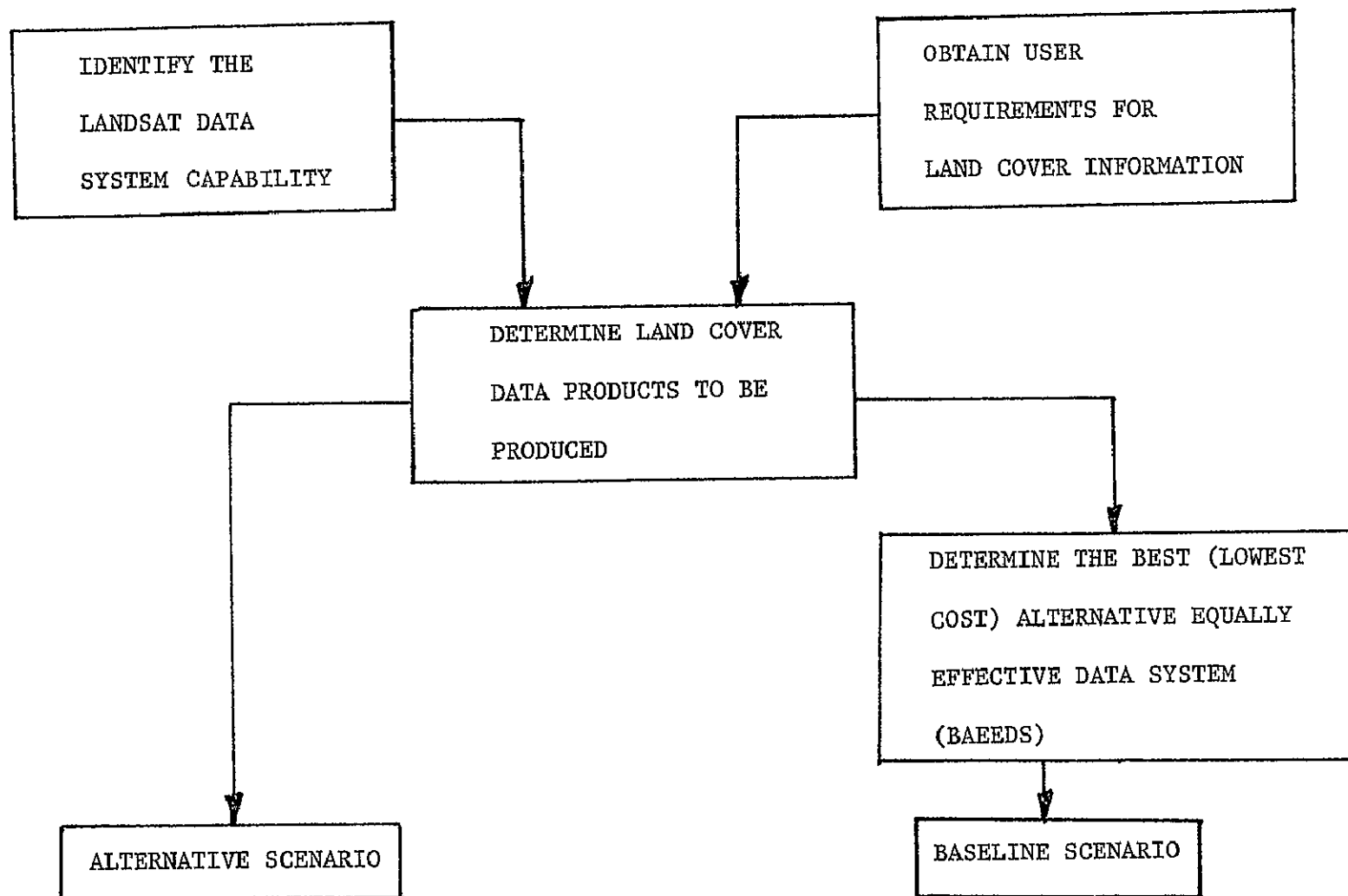


Figure 3-2. Approach to Developing Scenarios

terms of the best alternative equally effective data systems (BAEEDS), and the data products previously identified. The alternative scenario which is to be compared in terms of cost and benefits relative to the baseline scenario is composed of the same set of data products -- again those previously identified -- and the acquisition system of Landsat data systems. In summary, then, the baseline scenario is defined as high altitude aerial photography, manual photo interpretation, land cover products reflecting twenty-one land cover classifications. The data products schedule is broken into two segments of time. The period between 1977 and 1980 involves producing map products and statistics to be provided to the user community. In 1981 and after, map products and digitized data are assumed to be provided to the user community. The acquisition system in the baseline scenarios, high altitude aerial photography is deemed to be the most practical alternative to Landsat which could yield wide area land cover data products with adequate resolution at an acceptable frequency of update. The alternative scenario is composed of a multi-spectral scanner on the Landsat 2 satellite providing four channels of data on tape and the ERDAS processing system which performs the rectification, geo-referencing, classification processes. The alternative scenario ultimately leads to land cover products again consisting of twenty-one* land cover classifications equivalent to those available from the baseline. It should be emphasized that the schedule of data products produced in each scenario is identical. Both produce the same map products and statistics between the years 1977 and 1980, in 1981 and thereafter both would yield the same map products and digitized data to the user community.

3.5 Benefit Categories

3.5.1 Introduction

A point about the benefits to be derived from the Landsat data system should be emphasized to prevent their being undervalued. The benefits referred to earlier and summarized in Figure 3-1 represent potentially substantial improvement from the current capabilities in these functional areas.

*See note on bottom of Table 3.7 and the specific land cover classifications shown in Table 3.6.

TABLE 3.8

CATEGORIZATION OF USERS BY FUNCTION

<u>User Agency</u>	Category I			Category II		
	<u>Planning</u>	<u>Permitting</u>	<u>Enforcement</u>	<u>Resource Use</u>	<u>Productivity</u>	<u>Investment</u>
1. DNR/EPD/LPB		X	X			
2. Ga. Forest Research Council	X					X
3. Ga. Forestry Commission				X	X	
4. DNR/EPD/WPB	X	X	X			
5. USDA/SCS	X			X	X	
6. US Army Corps of Engineers	X	X	X			
7. US Army Fort Benning	X					
8. DNR/Game & Fish	X			X	X	X
9. DNR/OPR	X					X
10. Univ. of Ga./Agricultural Econ.	X					
11. APDC	X					X
12. USDA/FS	X			X	X	

That is, the physical benefits derived from Landsat data products are rightly measured in terms of changes from existing condition or improvements in the status quo. The analysis herein does not attempt to establish the value of the benefits themselves; it addresses the worth of the LDS which produced those benefits at some cost. To value the LDS, alternative ways of obtaining the same expected benefits are compared. It could be argued that these benefits are worth at least what the user community is willing to pay, i.e., Landsat costs and any other incremental costs not presently incurred. This sort of information as previously noted would be almost impossible to estimate with any degree of confidence. Fortunately, it is peripheral to the present study which addresses the worth of the remote sensing technology itself, the LDS, by employing a cost-effectiveness approach to the cost benefit analysis.

Beyond the dollars and cents analysis of the LDS, it is important to identify and characterize any directly related benefits in real terms if the merits of the LDS are to be fully appreciated. It is useful then to describe the desirable physical changes (benefits) which could be expected if LDS-type land cover information were to become routinely available to public agencies within the State of Georgia. The benefits derived from LDS land cover information have already been identified in terms of the functions performed by the family of user agencies in pursuing certain public objectives. These benefits are discussed briefly below. Where practical these benefits were modeled so that they might be expressed in quantifiable measures for later evaluation. These detailed models of the LDS benefits, their underlying assumptions and their derivations, though not necessary to following the present discussion, are given in Appendix III. It is expected that after some public agency operating experience with the LDS has been gained and some performance data has been collected, benefit models, such as those in the appendix, may provide useful tools for assessing the impact of the LDS.

3.5.2 The Planning Function

The general objective served by planning within the State of Georgia is to make more effective use of state funds. In the short run, this is

associated usually with the allocation of an annual budget to the various state agencies. Landsat may provide input information into this budget allocation process which is needed for efficient planning. This input information may be more information than is presently available for the planning process or it may be in some sense equivalent information that is presently being used but the Landsat information would presumably be available at a lower cost than the present information. The long run aspects of planning are to provide for future needs of the state. Long run planning in general requires some forecasting in order to project future needs and resource availability. It is in this forecasting effort that Landsat data might be used advantageously. Forecasts available with the better data from the Landsat data system are expected to be more reliable and more accurate.

3.5.3 The Permitting Function

The permitting function is one of the mechanisms the State and the Federal Government uses to control the activities of individuals or agencies which have potentially damaging effects on the general public. The activities of interest in the present study are those related to land use and land cover. Certain land uses in particular circumstances can lead to high social costs in terms of air and water pollution and their attendant consequences on the safety and health of the public.

The permitting function is a passive function. It does not involve selecting sites but rather entails evaluating sites which have been proposed by parties applying for permits. This passive mode of operation is one which minimizes intrusion on the freedom of choice of applicants while still safeguarding the public interest.

Typically an applicant selects a site for conducting an activity in such a way that his particular interests are best served. Examples of criteria an applicant might reasonably apply in site selection are land cost, distance to a service area, accessibility from major transportation arteries, tax base implementations, etc. Having selected a site for an activity, an applicant makes a formal request to the permitting authority for site approval. The permitting authority applies minimum standards and experience based

judgement to determine if a proposal site is acceptable. The standards applied in approving a site do not necessarily reflect the criteria applied in selecting a site; in fact, the standards are usually at odds with the applicants site selection criteria. The inherent divergence of interests requires that each permit application be checked carefully.

Where the permitting function addresses land uses which are related to the land cover, some savings may be available from using Landsat data. If Landsat can provide accurate, reliable information on land use near a proposed site, some presently incurred site inspection cost can be avoided. Further, for those applications which can be rejected just on the basis of local land cover, the cost of a trip to the site could be avoided. The benefits derived from Landsat, then, are dependent upon the rate at which permit applications are received, the cost of an on-site inspection of local land cover, the application rejection rate where rejection is based on local land cover, and the cost to send an inspection team out to a proposed site.

These savings may reflect dollars accruing to either the application or the State depending upon the fee structure established for obtaining permits. Regardless of how the savings are apportioned, a real savings in resources will be realized in the process of arriving at an approved site.

3.5.4 The Monitoring Function

The general mission performed in a monitoring function is to detect problems in the field that have potentially damaging effects on society or on property. A large amount of the monitoring activity conducted within the State involves enforcing requirements which are associated with permit approvals. More generally though, problems of interest are those permit violations of hazardous conditions which are reflected in land cover. Five assumptions are made in developing a model for the monitoring functions. First, damage caused by some permit violation or hazardous condition is directly related to the length of time such a condition goes undetected. The second assumption is that some of the conditions of interest can be detected on the basis of land cover information. A third assumption is that state

resources, manpower, and facilities presently devoted to enforcing and monitoring activities can productively be employed elsewhere. The fourth assumption made in the model is that Landsat data has, in fact, adequate resolution for detecting the conditions of interest. The fifth assumption is that Landsat has no effect on established inspection cycles. That is, the period inspection of field conditions will continue with the same frequency regardless of the source of land cover information.

The models focus on the change in the duration of undetected problems in the field. The structure being modeled reflects two conditions: first, the problems or violations arise in unpredictable times. Second, the detection of problems or violations in the field is a function of data collection itself. Figure 3-3 is a schematic indicating the character of the problem. Potential problems and violations arise or occur, if you will, at random points in time and they become real problems in the field. Figure 3-3 denotes this as potential problems arising to a state defined as existence. The objective of the state agency with a mission of enforcing and monitoring is to detect problems in the field and either resolve them or report them to other agencies to take appropriate actions. The essential activities of interest is detection.

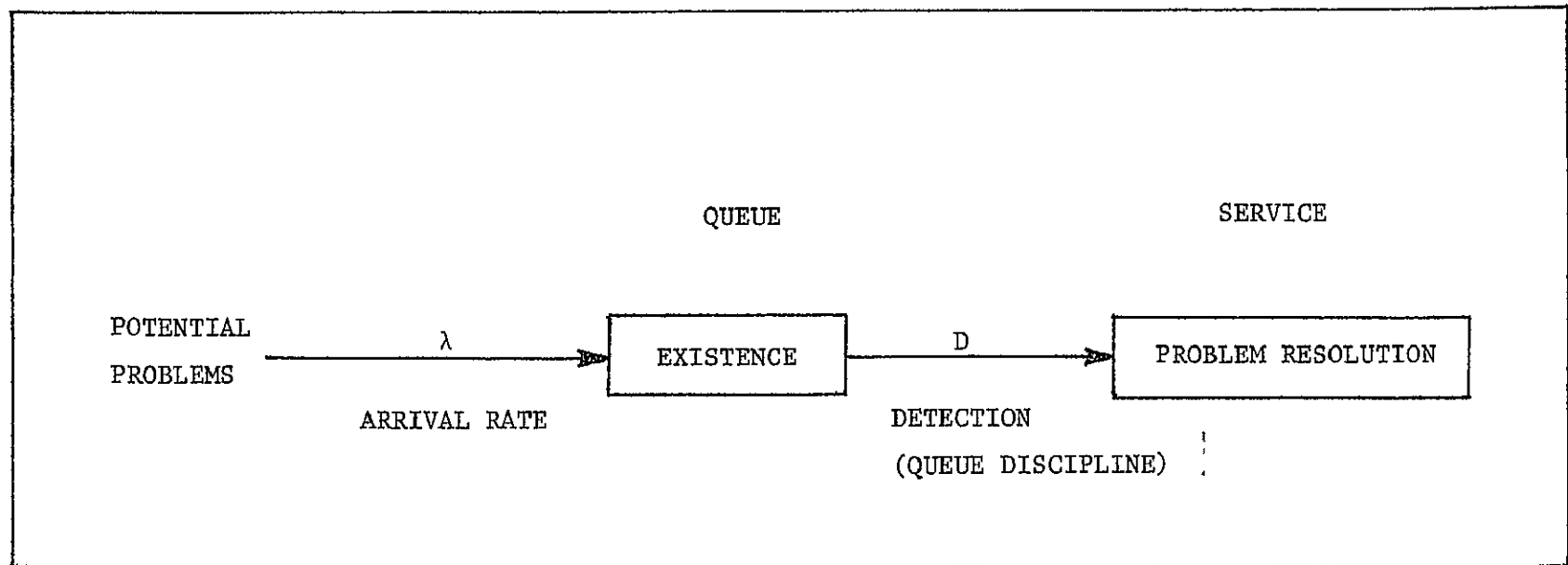


Figure 3-3. Queuing Model of the Monitoring Function

SECTION 4

QUANTATIVE ANALYSIS

Figure 4-1 presents an overview of the elements in the cost analysis used in valuing the Landsat Data System (LDS). The schematics show the relative levels of cost associated with generating the data products defined in Table 3.7 using the LDS and the BAEEDS. It should be recalled that the combination of the data products and the LDS comprise what is referred to as the alternative scenario, the data products and the BAEEDS constitute the baseline scenario. The schematics show two streams of cost between the years of 1977 and 1985. The year 1985 has been selected as the terminal year and as a reasonable time horizon within which to conduct the analyses. Adjacent to each of the figures is an expression for the present value of the costs which is simply a discounted sum of the annual cost over the planning horizon. Given that both the baseline and alternative scenarios reflect the same set of data products produced on the same production schedule, a meaningful comparison between scenarios can be made in the terms of the differences in the present value cost. At the bottom of Figure 4-1, this comparison is indicated in the expression for the net present value of the Landsat data system. The NPV (LDS) equals the present value of the available cost savings if land cover information is obtained using the Landsat data system instead of using the best alternative equally effective data system.

4.1 Scenario Assumptions

Six major assumptions underlie the quantitative analysis of the Landsat data system. Some of these have been briefly discussed earlier. Limiting the scope of the study is an assumption that the LDS is characterized by the Landsat 2 satellite's capabilities. These have been implicitly accounted for in the landcover classifications included in the data products shown in Table 3.7 and in the cost of processing data having a 1.1 acre resolution. A second assumption being made is that the user community within Georgia will have an operational need for digitized data products beginning in 1981. This assumption gives rise to the change in the data products beginning in 1981. A third assumption underlying the economic analysis is that the Landsat data

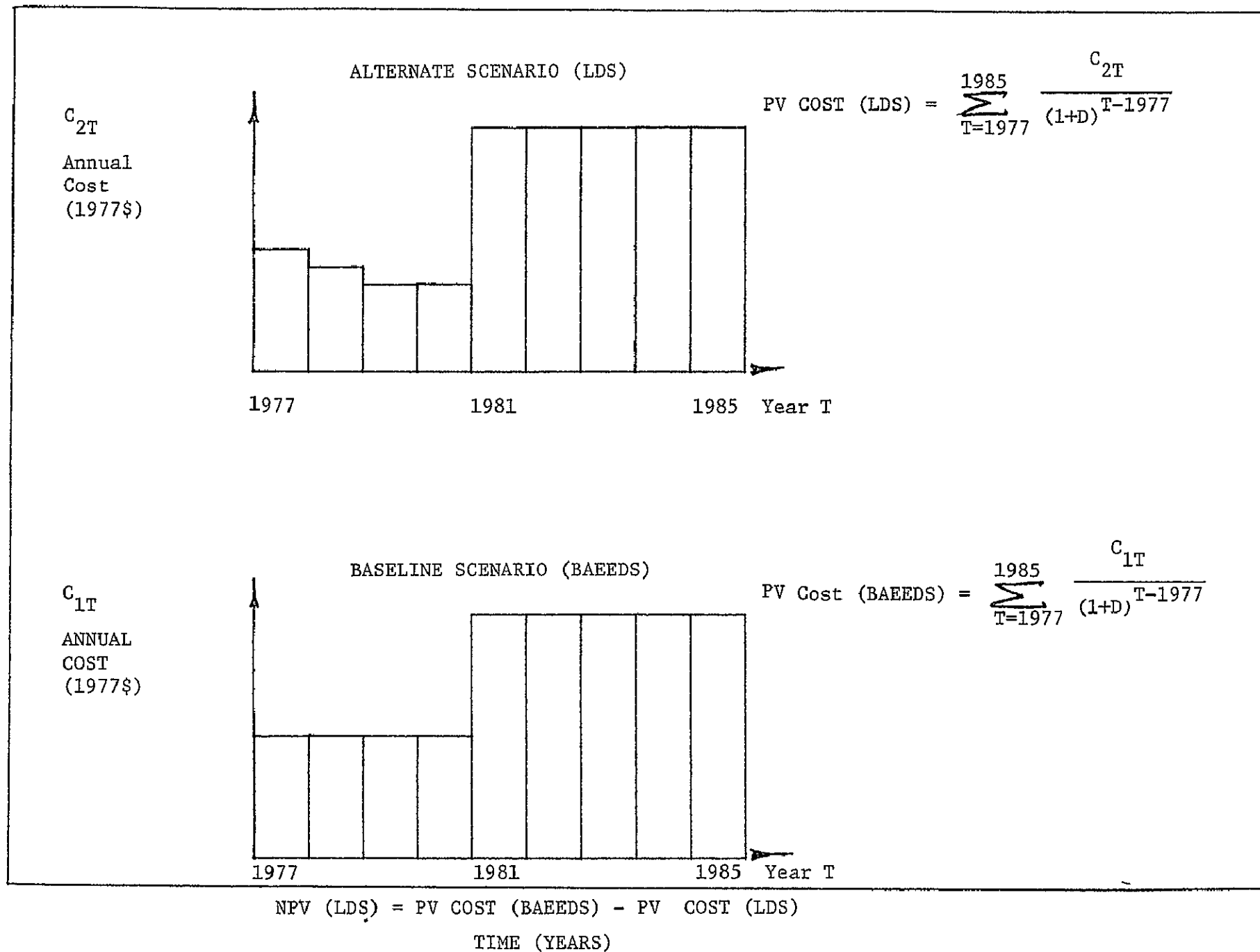


Figure 4-1. Overview of the Cost Analysis

system value can be estimated in terms of opportunity cost. The basis for this assumption lies in an assumption stated earlier in the choice of the analysis technique used in the investigation. If the data products obtained by the user community are both necessary and sufficient to their needs then the value of the LDS is the cost saving available by virtue of acquiring its data products from Landsat rather than from the best alternative acquisition system. A fourth assumption made in the analysis is that the best alternative equally effective data system is high altitude photography with the most cost efficient data processing. This assumption is based on the observation that, excepting the LDS, high altitude photography is clearly the most economical means of obtaining wide area landcover data products on a fairly frequent basis. A fifth assumption implied in the analysis is that photo interpretation for landcover information will remain largely a manual process at least till the end of the planning horizon in 1985. Equivalently, this assumption states that there will be no technological improvement in the area of automated photo interpretation techniques. The last major assumption underlying the analytical results is that the acquisition costs for ERDAS are sunk. In the present study, the LDS in the State of Georgia, the sunk cost assumption is deemed appropriate inasmuch as funding for the design and development of the ERDAS system has already been committed and these costs are largely not recoverable. In the more general cases, the LDS being evaluated for use in different geographical areas wherein no ERDAS system or comparable system acquisition costs had been incurred, those costs would rightly be considered in valuing the LDS.

4 2 Important Parameters

Two important parameters in the analysis are the scale of the map products produced for the time horizon during which the subject data products are expected to be an important constituent in the state's overall data base and the discount rate by which future costs are translated into present values. This discount rate is analogous to the discount rate applied in making private capital investment decisions. The specific discount rate

appropriate to an analysis of the State of Georgia's use of the LDS is a discount rate identifiable with the state's population as a whole, i.e., a public or social discount rate. Typically the social discount rate is somewhat less than the private discount rates of the individuals or private economic interests within the state. Other parameters in the analysis include the per square mile aerial survey cost reflecting the cost of the aircraft and the photography required to obtain one set of color infrared prints. A parameter costs per square mile of photo interpretation is used to estimate the cost of transforming photographs into summary statistics. This cost reflects a process which is largely a manual delineation of areas shown on photographs using simple planimeter-type devices. Additional parameters for the cost effectiveness quantitative analysis are the per square mile cost of each photo mosaic data product and the cost of digitizing the data extracted from photographs. On the Landsat side of the cost comparison, the parameters of interest are the acquisition cost for a Landsat tape, the set up cost required in processing tapes; per square mile cost for rectification and geo-referencing of the raw data, for the collection of training samples information, for data classification into digitized landcover information; and finally the per square mile cost of producing color coded mosaic maps from processed data. Another cost considered in the analysis is the per copy cost duplicating data products incurred when users receive identical data products. Additional costs associated with the ERDAS system are the annual cost associated with maintaining the system and general overhead expense. A comparable figure for a system employing periodic aerial surveys is associated with maintenance and general administration of the data system. The remaining cost elements which have already been mentioned are the sunk costs summarily described as ERDAS equipment and equipment installation costs.

The data used in the costs analysis were collected from various sources. Table 4.1 gives the general data source list from which the input information was collected. Table 4.2 shows a category by category delineation of the components of the annual costs for a single year of operation for both

TABLE 4.1
COST PARAMETER DATA SOURCES

PARAMETER	SOURCE
AIRCRAFT COST	Ga. DOT, Manual of Remote Sensing, Landsat Document published by Bendix Corporation, 2 September 1977
PHOTO PROCESSING	Commercial Quotes, Manual of Remote Sensing
DIGITIZING COST	USGS (LUDA), Remote Sensing of Earth Resources, Vol. IV
PHOTO INTERPRETATION	Remote Sensing of Earth Resources, Vol. IV, Manual of Remote Sensing, USFS, USGS (LUDA)
ALL LANDSAT/ERDAS COSTS	Estimated by Georgia Tech personnel who designed/built/operated Landsat data processing system

TABLE 4.2
NOMINAL CASE ONE-YEAR COSTS
(Acquisition and Processing 4 Times Per Year) *

BAEEDS	LDS
<u>Color IR Photos</u> 4x59,000 sq. miles @\$4/sq. mile \$944,000	<u>Image Acquisition</u> 4x14 scenes @ \$200/scene \$11,200
<u>Manual Interpretation for Statistical Summary *</u> 4x59,000 sq. miles @\$0.60/sq. mile \$141,600	<u>Computer Set-up</u> 4x\$550/Acquisition 2,200
<u>Color Mosaic Negative</u> 4x59,000 sq. miles @\$0.50/sq. mile \$118,000	<u>Processing</u> Rectification/Georeference \$0.30/sq. mile Classification \$0.10/sq. mile Training Sample Selection \$0.06/sq. mile \$0.46/sq. mile 4x59,000 sq. miles @\$0.46/sq. mile \$108,560
<u>Color Maps from Mosaic Negative</u> 4x7 users @ \$175/map \$ 4,900	<u>Statistical Summary</u> 4x59,000 sq. miles @ \$0.00/sq. mile \$ 0
<u>Program Administration</u> \$ 25,000	<u>Color Mosaic Negative</u> 4x59,000 sq. miles @ \$0.15/sq. mile \$ 35,400
<u>TOTAL BAEEDS ANNUAL COST.</u> <u>\$1,233,500</u>	<u>Color Maps from Mosaic Negative</u> 4x7 users @ \$175/map \$ 4,900
Note: Cost Added by Manual Digitization (to begin in 1981) 4x59,000 sq. miles @ \$3.75/sq. mile \$855,000	<u>Overhead and Maintenance</u> \$ 35,000
	<u>TOTAL LDS ANNUAL COST:</u> <u>\$197,260</u>

* As shown in the sensitivity analyses, the value of Landsat is relatively insensitive to tape cost and photo interpretation for statistical summary.

scenarios: the baseline reflecting the best alternative equally effective data system on the left and the alternative corresponding to the Landsat data system cost on the right. The note on the best alternative equally effective data system cost sheet gives the cost estimate of the effect of adding in 1981 a requirement to produce digitized data products. It should be noted that no such additional 1981 cost is required for the Landsat data system inasmuch as digitized data already underline all its data products.

A computer program in FORTRAN IV code was written to carry out the cost analyses of the two alternatives and perform the appropriate present value computations. The computer program is flow charted and documented in Appendix IV. Its inputs and outputs are fully described so the program can readily be used for making further similar computations should they be desired.

4.3 Results

Figure 4-2 is a graph of the annual costs of generating the desired data products for the years 1977 through 1985. The vertical axis is annual cost expressed in 1977 dollars. The horizontal axis is the year. The upper curve labeled BAEEDS, best alternative equally effective data system, shows the annual cost for generating the data products using a high altitude photography data collection system. The lower curve labeled LDS, Landsat data system, shows comparable annual cost figures for generating the same data products using the Landsat data collection system. At the top of the figure the net present value of the Landsat data system is shown \$9.474 million dollars in 1977 dollars. This figure is the present value of the stream of differences in annual cost between the two curves discounted at an annual rate of 7%. This present value figure is for the nominal case where all the input values for the parameters in the analysis were taken at their expected or nominal values. Some of these nominal values may, in fact, be low, while others might actually be high. In order to give some indication how such departures from expected values could impact the net present value of the

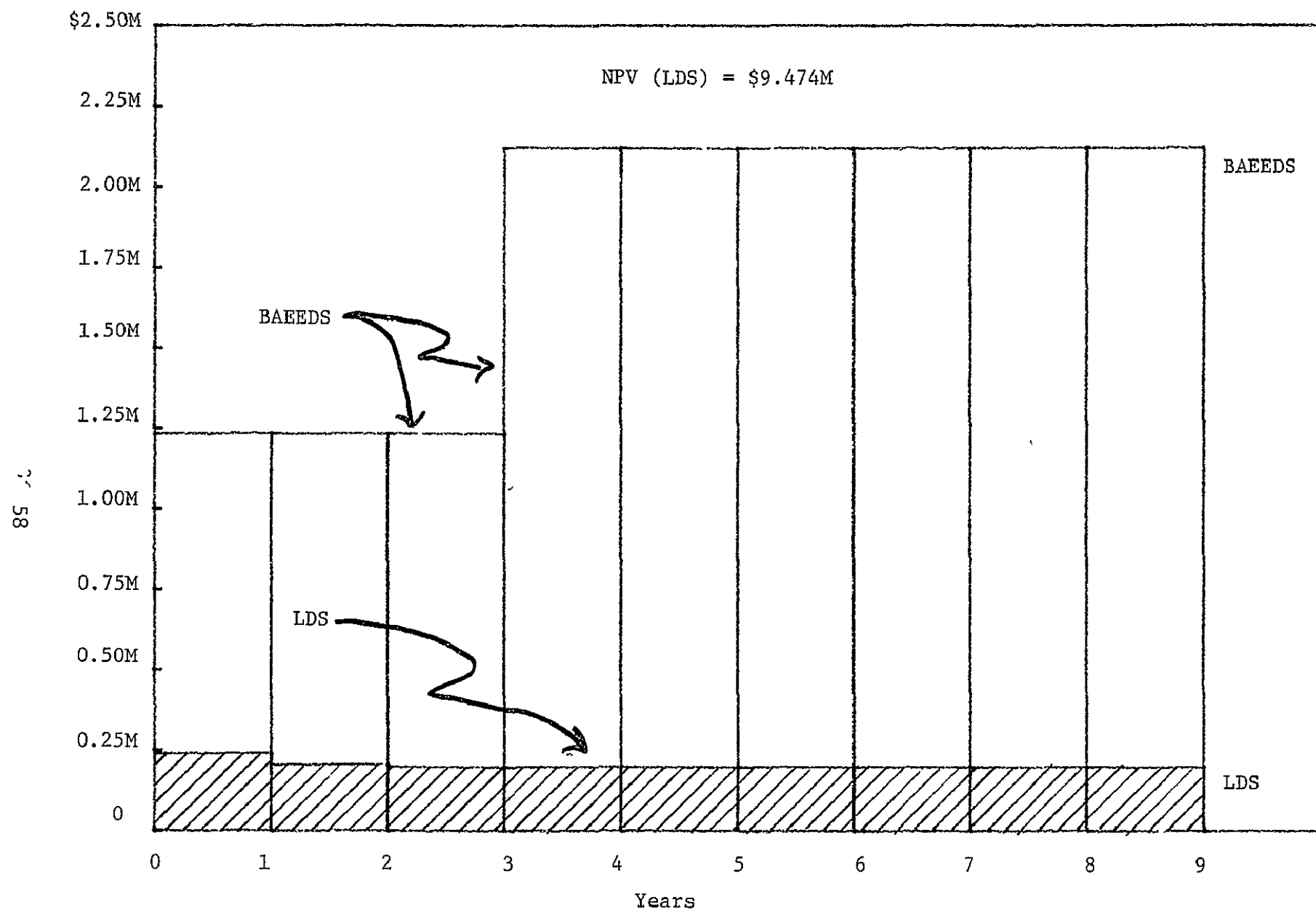


Figure 4-2 Nominal Case Annual Cost of Data Systems vs. Time (1977 \$)

TABLE 4.3
UPPER AND LOWER BOUNDS ON LDS VALUE

	LDS	BAEEDS	NPV (LDS) (Millions of 1977\$)
Best Case	75% NLC	125% NLC	12.491
Nominal Case	NLC	NAC	9.474
Worst Case	125% NLC	75% NAC	6.457

NLC Nominal case Landsat cost
NAC Nominal case Aerial Photo cost

Landsat data system, two extreme cases were considered. Table 4.3 shows upper and lower bounds on the net present value of the Landsat data system. These upper and lower bound estimates were computed as follows. The two annual cost streams shown for the nominal case in Figure 4-2 are used to define the nominal Landsat cost, denoted NLC, and the nominal aerial photo cost case denoted NAC. Combining these yielded a net present value of just under 9.5 million dollars. A best case in terms of the valuation of LDS has been defined in the table as that case where the Landsat data system cost are taken at only 75% of the nominal Landsat cost and simultaneously the best alternative equally effective data system are assumed to cost 125% of what had previously been denoted being nominal alternative system cost. This combination of low cost for LDS and high cost for the BAEEDS yields a net present value for the LDS of \$12.50 million. This is a subjective estimate of the most that the LDS is worth over the time frame 1977 through 1985. Similarly in the table, a worst case is defined and in this worst case yields a low value of Landsat. It is assumed that the nominal Landsat costs were under estimates of what Landsat would in fact cost. For the worst case, Landsat costs were taken to be 125% of the nominal Landsat cost. Concurrently with this expectedly high estimate of the Landsat cost, it is assumed that the alternative system cost would in fact be lower than previously expected. To indicate this, the best alternative equally effective data system cost, taken to be only 75% of the nominal costs for the alternative data system. With this combination of high Landsat data system cost and low alternative equally effective data system costs the net present value of the Landsat data system is reduced to \$6.5 million. This is a subjective estimate of the least that the LDS is worth over the time frame, 1977 through 1985. There is no guarantee that the actual net present value of the Landsat data system will be in the range \$6.5 to 12.5 million but it is very likely that this will be the case. Combinations of cost conditions which would cause it to fall outside that range appear highly unlikely.

The quantitative analysis presented in this section was made for the nominal case in which nominal values were used for the baseline and alternative scenario parameters. Since these values were considered to be nominal values, they, in practice, can vary over some range. What impacts on the results do variations about the nominal value have was investigated in the form of sensitivity analyses.

SECTION 5

SENSITIVITY ANALYSIS

5.1 Parameters

Table 5.1 shows the parameters which were subjected to some perturbation in order to establish the sensitivity of the net present value of the Landsat data system. These cost factors were selected primarily because there was some uncertainty associated with their best estimate values and/or because the nature of the parameter was such that it might be of particular interest to the decision maker in determining the worth of the Landsat data system. In the nominal case photo acquisition costs which includes both the flight cost of the aircraft and costs of the photographs has a value of \$4 per square mile. A reasonable range deemed to be appropriate for this input parameter spans from \$3 to \$5 per square mile. The Landsat tapes presently available for \$200 per scene might conceivably be priced to take on values anywhere from zero to \$500 per scene. That is, if NASA provided these tapes with no charge to the states their cost would be zero or conceivably prices might be increased based on some alternative pricing scheme to some higher values assumed in the computations to be up to as much as \$500 per scene.

Photo digitization costs which originally had been estimated at \$3.75 per square mile was allowed to range between zero dollars per square mile and \$7.50 per square mile. Due to the very limited experience upon which the digitizing cost estimate is based, this cost factor is highly uncertain and may be a highly unreliable basis for estimating future costs. The \$3.75 figure is a composite number based on assumptions about camera focal length, aircraft altitude, aircraft flightlines and photo overlap, cell size, skill level/wage rates of the personnel performing this digitization process. The zero figure, one extreme treated in the sensitivity analysis, might be construed as a relaxation of the previously stated assumption that photo digitization will remain a largely manual process throughout the time frame of interest. If in fact digitization techniques become highly automated, this cost element may be reduced dramatically so that zero dollars per square

TABLE 5.1
SENSITIVITY ANALYSIS

<u>Cost Factor</u>	<u>Nominal</u>	<u>Low - High Value</u>
Photo Acquisition	\$4/Sq. Mile	\$3-5/Sq. Mile
Landsat Tapes	\$200/Scene	\$0-500/Scene
Photo Digitization	\$3.75 Sq. Mile	\$0-7.50/Sq. Mile
Photo Interpretation For Statistical Summary	\$0.60 Sq. Mile	\$0.20-1.00/Sq. Mile
Discount Rate	7%	2-12%

mile might be a good approximation in this situation. The \$7.50 figure corresponding to the high value considered for photo digitization costs simply reflects the fact that a large variation in this cost factor might not be inconceivable. The nominal value of the photo interpretation, statistical-summary cost factor taken to be 60¢ per square mile, was deemed to be a fairly reliable estimate. Still, statistical summary costs do depend significantly on the quality of the photography and the skill of the interpreter. Some variation in this cost factor might be expected. A range of values from 20¢ to \$1.00 per square mile is considered in the sensitivity analyses. The final cost factor subjected to examination is the discount rate used in computing the net present value of the Landsat data system. The nominal value of 7% is approximately what the federal government recommends for analysis of public investment involving planning for water and related natural resource investments. Other federal investments are typically analyzed using a discount rate of approximately 10%. Precise guidelines and explicit formulas exist for establishing the appropriate discount rate. Summary statements of such schemes are given in the Federal Register dated September 10, 1973, Volume 38, No. 174, Part III. In this analysis, the discount rate was allowed to take on values over the range from 2 to 12%.

5.2 Calculated Results

Figure 5-1 shows how the net present value of the Landsat data system changes with changes in the discount rate. Net present value of Landsat goes from roughly 7.5 million dollars at a discount rate of 12% per annum to a value of a little over 12 million dollars with a value of the discount rate is lowered to 2% per annum. Figure 5-2 shows sensitivity of the Landsat data system present value to variations in the photo digitization costs. A similarly wide range of values from over \$6 million to approximately \$12 million is possible as the digitization cost increases from zero to \$7.50 per square mile. It should be noted that in Figure 5-2 that even if digitization cost were zero the net present value of the Landsat data system would still be appreciable, over 6 million dollars. Despite the fact that the digitization cost input parameter has a fairly high level of uncertainty associated

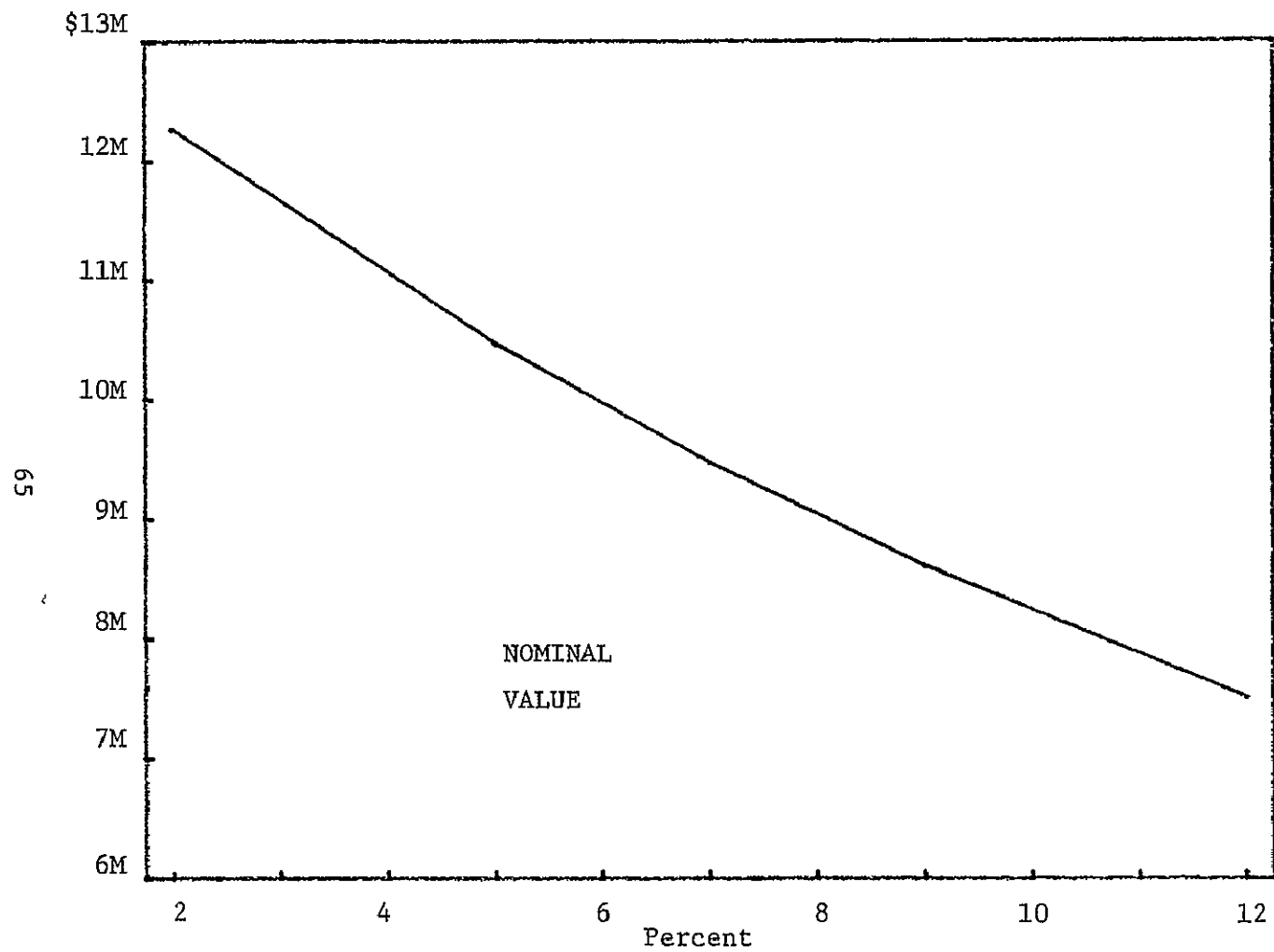


Figure 5-1. Net Present Value vs Discount Rate

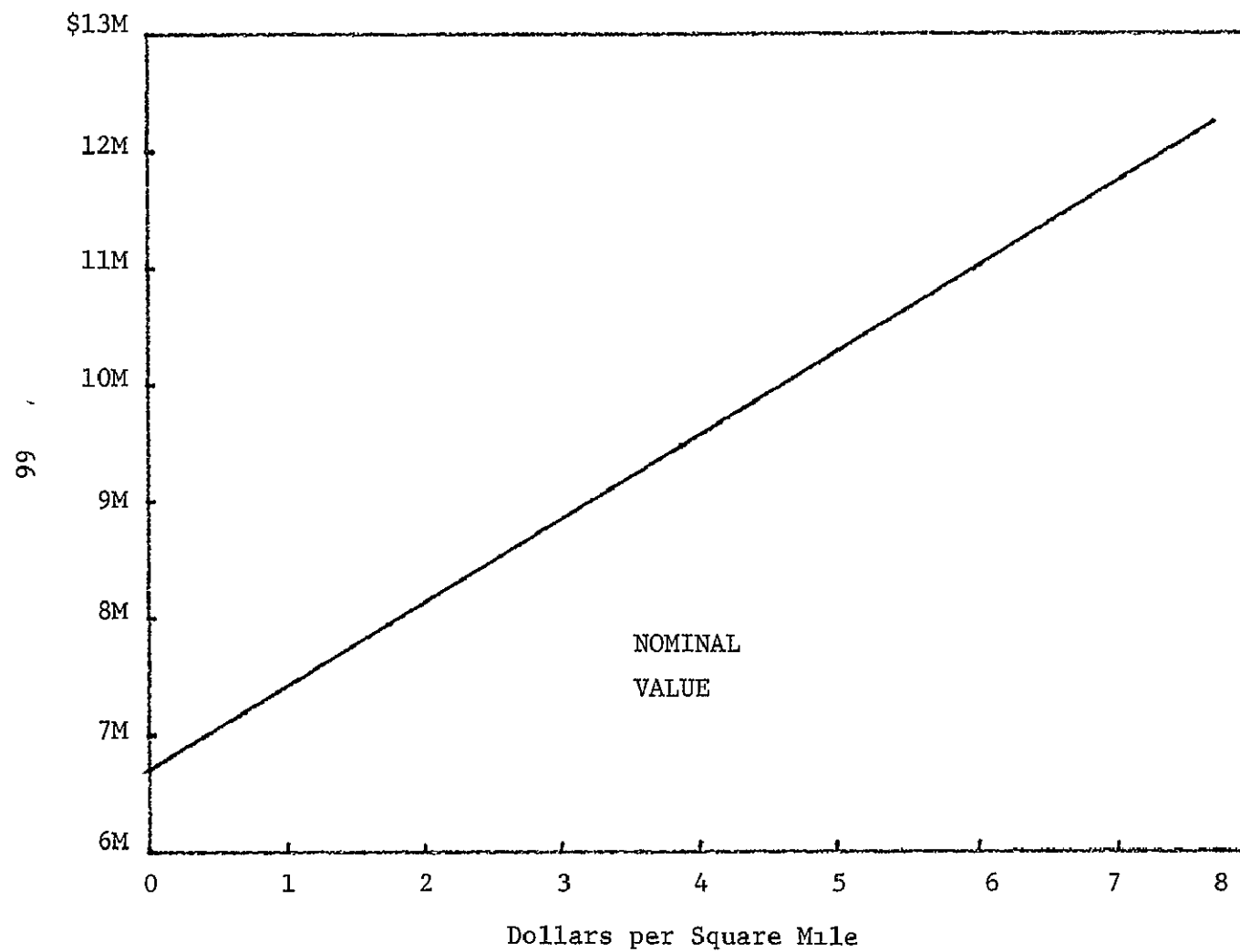


Figure 5-2. Net Present Value vs. Photo Digitization Cost

with it, it does not negate the conclusion that the Landsat data system has an appreciable net present value. Figure 5-3 shows the variability in the net present value of the Landsat data system when photo acquisition cost changes. A range for photo acquisition costs from \$3 to \$5 results in the net present value of Landsat to increasing from \$7.9 to \$11 million. Landsat values appear somewhat less sensitive to photo acquisition costs than they were to either the discount rate or the digitization cost factors.

Figure 5-4 shows the sensitivity of the Landsat data system value to changes in the costs of photo interpretation. The figure shows very little change in Landsat value over a wide range of possible interpretation costs per square mile. Figure 5-5 shows the sensitivity of the Landsat data system value to the acquisition price of the tapes procured by state agencies from NASA. The very flat curve indicates extremely little sensitivity of the Landsat data system value to change in price of raw data tapes. Figure 5-6 shows the sensitivity of the Landsat data system's value to variation in the cost of computer processing for the raw data tapes.

Table 5.2 gives a summary of the elasticities of the net present value for the Landsat data system at the nominal values of input parameters. This table shows the relative importance of the various cost parameters for the determining errors in the net present value of the Landsat data system about its nominal expected value. As can be seen from the table, the three most sensitive parameters are discount rate, photo acquisition, and photo digitization.

5.3 The Effects of Less Frequent Land Cover Information

The analysis has focused on a cost comparison of alternative equally effective data systems specifically a cost comparison of high altitude photography with the Landsat satellite multispectral scanner system. The rationale for this approach was presented earlier. An alternative however, which might be of some interest, is the following. Assume the data products shown in Table 3.7 are in fact to be acquired by some data acquisition system at some unspecified frequency. The question might be asked what comparison in terms of frequency-of-information update can be made, given that these data products may be provided using a Landsat data system or using high altitude photography. This comparison implies two alternatives that have

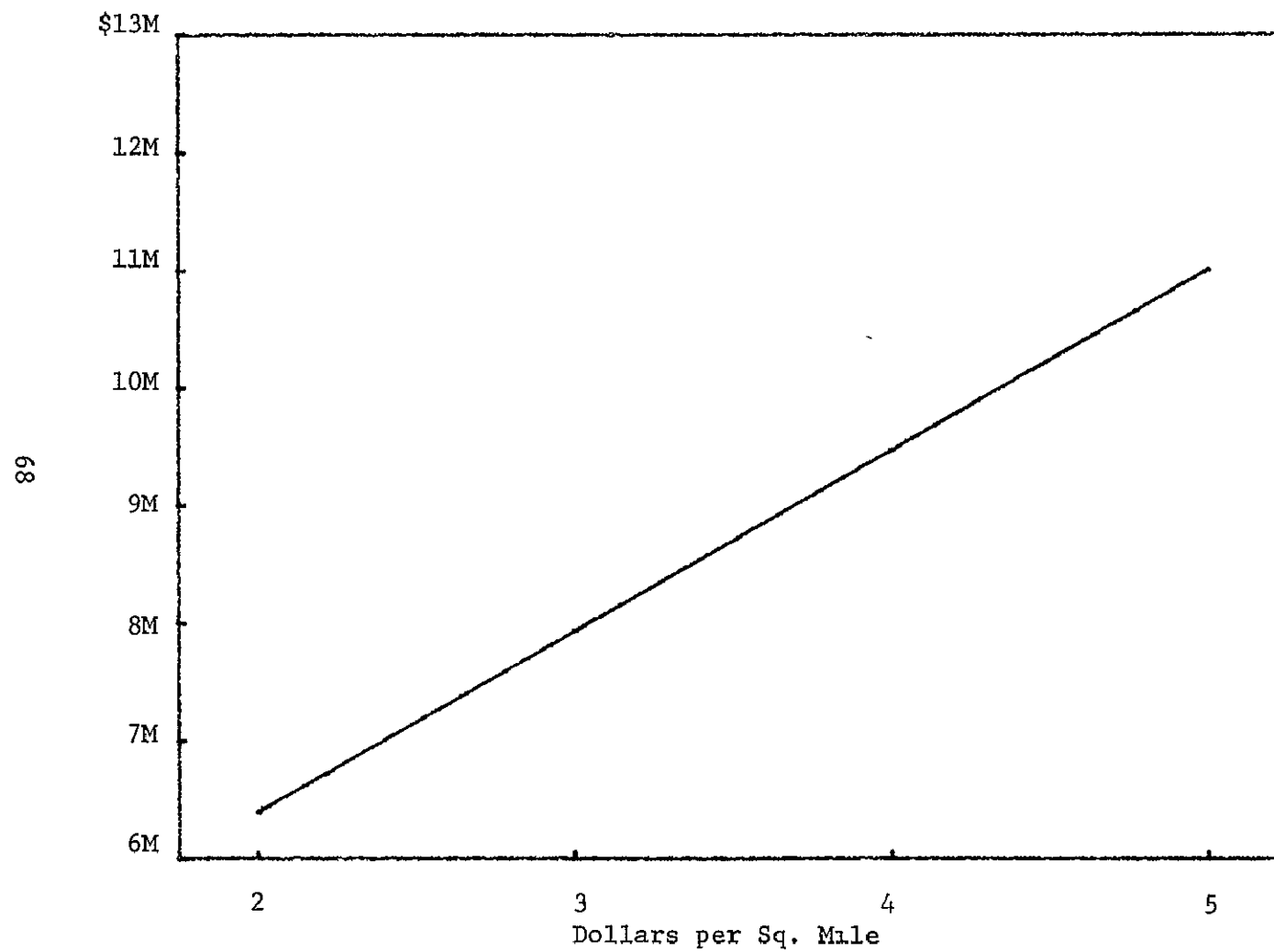


Figure 5-3. Net Present Value vs. Photo Acquisition Cost

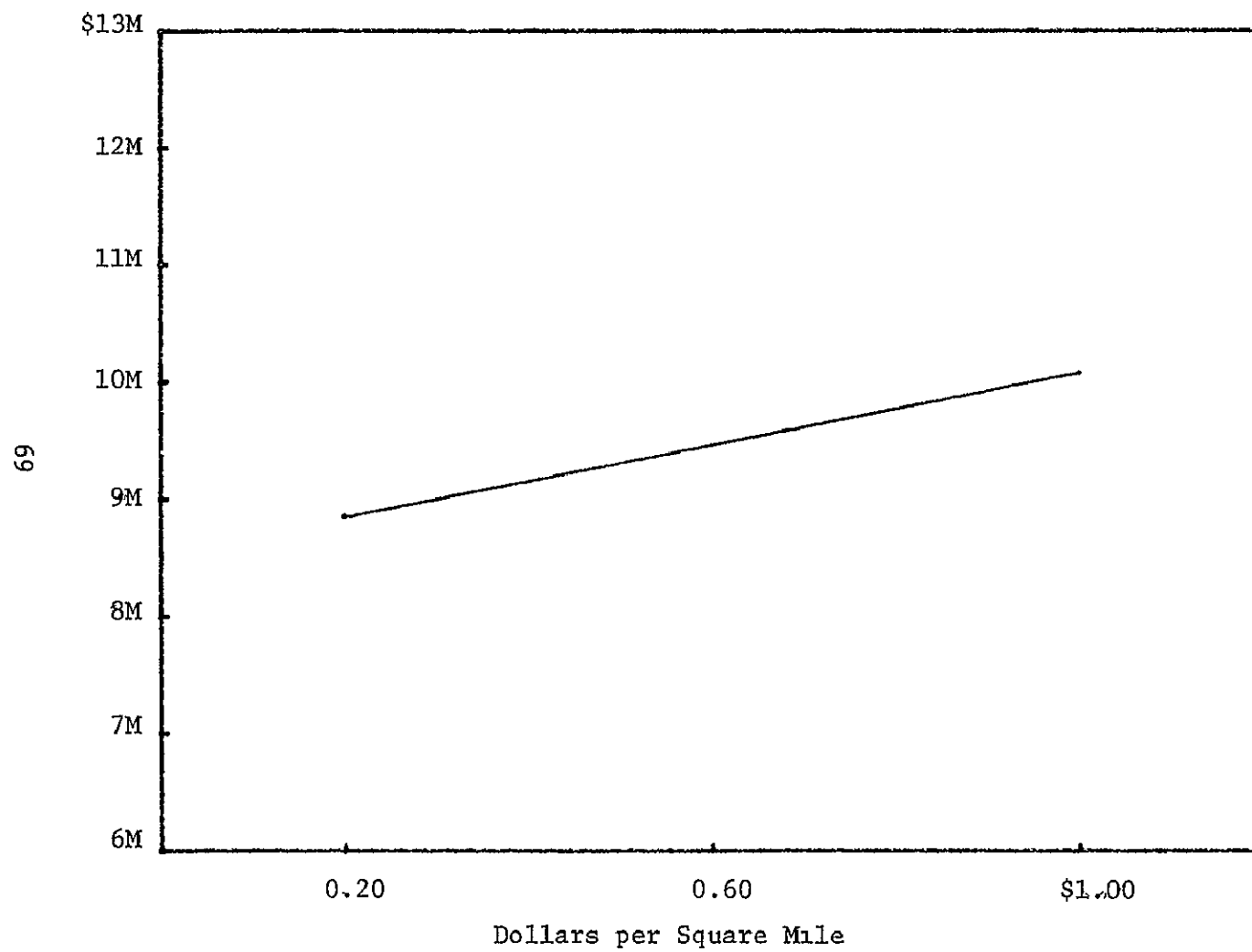


Figure 5-4. Net Present Value vs. Photo Interpretation Cost

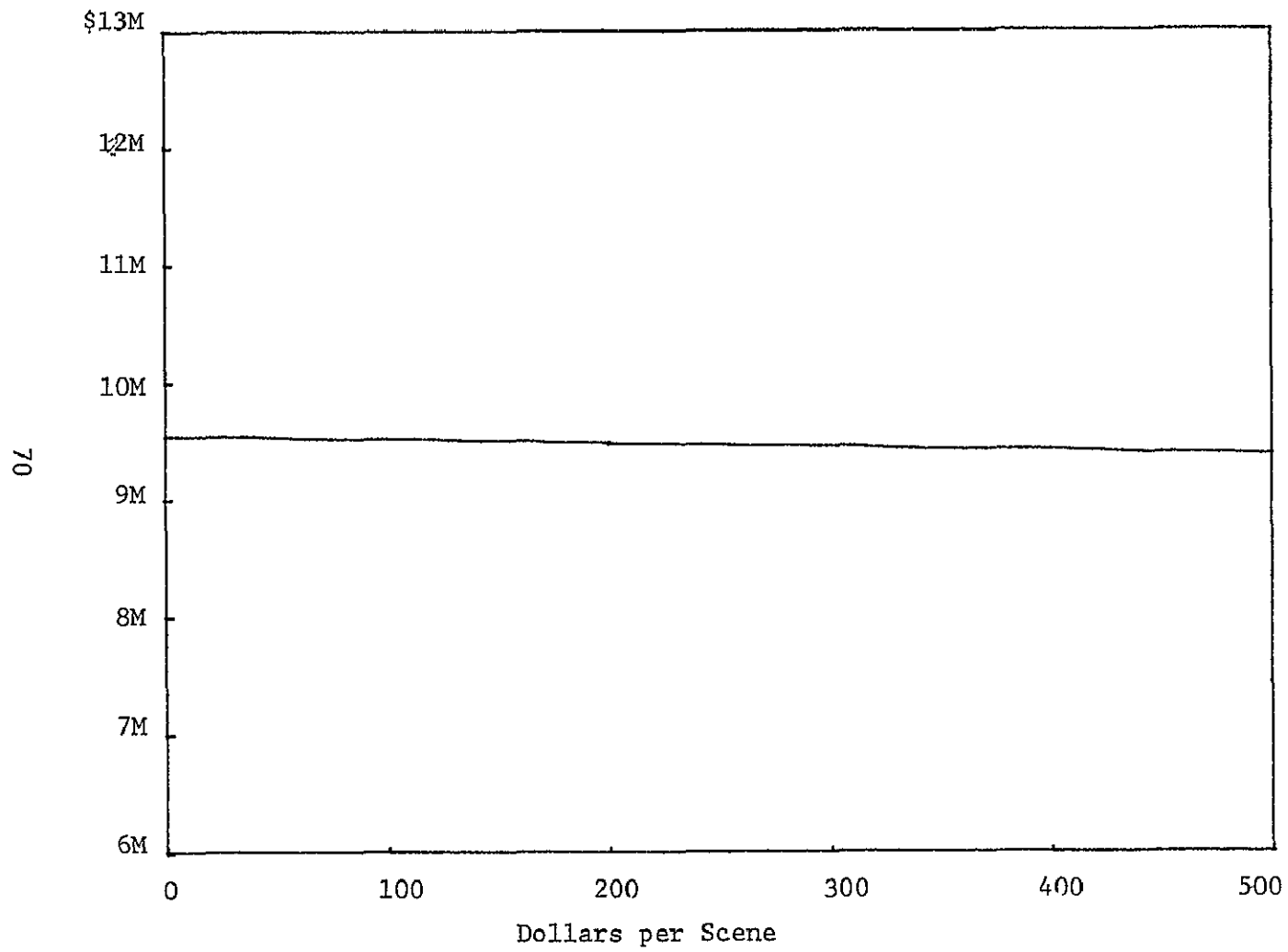


Figure 5-5. Net Present Value vs. Landsat Tape Cost

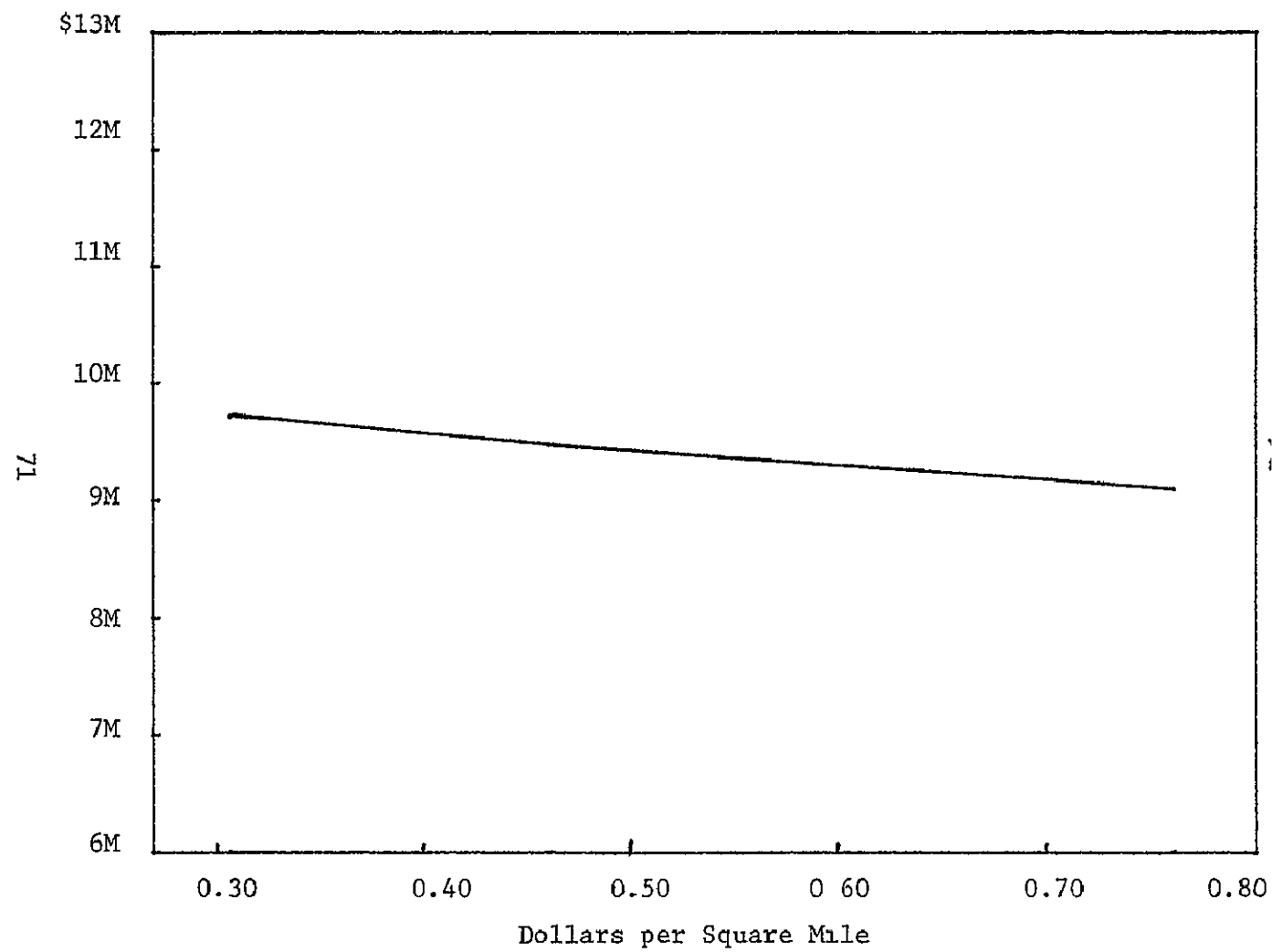


Figure 5-6. Net Present Value vs. Landsat Processing Cost

TABLE 5.2
COST ELASTICITIES OF LANDSAT VALUE

Cost Factor	Elasticity
Discount Rate	-0.7407
Photo Acquisition	0.6667
Photo Digitization	0.3115
Photo Interpretation	0.0947
Landsat Processing	-0.0796
Landsat Tapes	-0.0083

The numbers in the table are the percentage change in the net present value of the LDS which would result from a one percentage increase in a particular category of cost. The information in the table applies only to small departures from the input cost values used to define the nominal case. The table shows the relative importance of the various cost.

equal costs but differ in that they provide the specified data products at some unequal frequency. The ultimate distinction between the two systems in this mode might, in the enforcement function, extend the average length of time violations or problems in the field remain undetected. In a planning function less frequent data might typically degrade the accuracy of a forecast and thereby have possible detrimental effects on investment and public policy decisions.

Figure 5-7 and 5-8 are graphs of the comparison of Landsat with high altitude photography in a scenario where Landsat is providing data products to users on a quarterly basis whereas the high altitude photography is providing the same data products to the same user community but on a less frequent basis as indicated in the figures. Figure 5-7 shows the comparison when the data products are composed of aggregate statistics and maps, Figure 5-8 reflects digitized data and map data products. On the vertical axes present value of the data acquisition costs in 1977 dollars is shown. The curve labeled for Landsat data products acquired quarterly indicates the cumulative cost of providing quarterly data products using Landsat. The curve labeled for high altitude aircraft and photography at time T corresponds to the situation where at time zero a single set of land cover information is provided using the aerial acquisition data system and subsequent to the first set of data products a second set of data products is supplied to the users at different periods, T. At various values of T, the costs of providing data products to the user community using each schedule is computed and plotted to give figures on the curve in Figure 5-7 and 5-8.

The two curves cross in Figure 5-7 at an approximate value of $T=3$ years or roughly 9 quarters of a year and in Figure 5-8 at $T=7$ quarters. The significance of these points of intersection is that providing land cover products on a quarterly basis using Landsat is no more costly than providing these same data products every 3rd or 7th quarter using high altitude photography depending upon whether the data products reflect aggregate statistics or digitized data. This might be perceived as a budget constraint scenario or a comparison of equal budget alternatives for state agencies. Figures 5-7 and 5-8 afford an alternate perception and insight of the comparison of Landsat with high altitude photography.

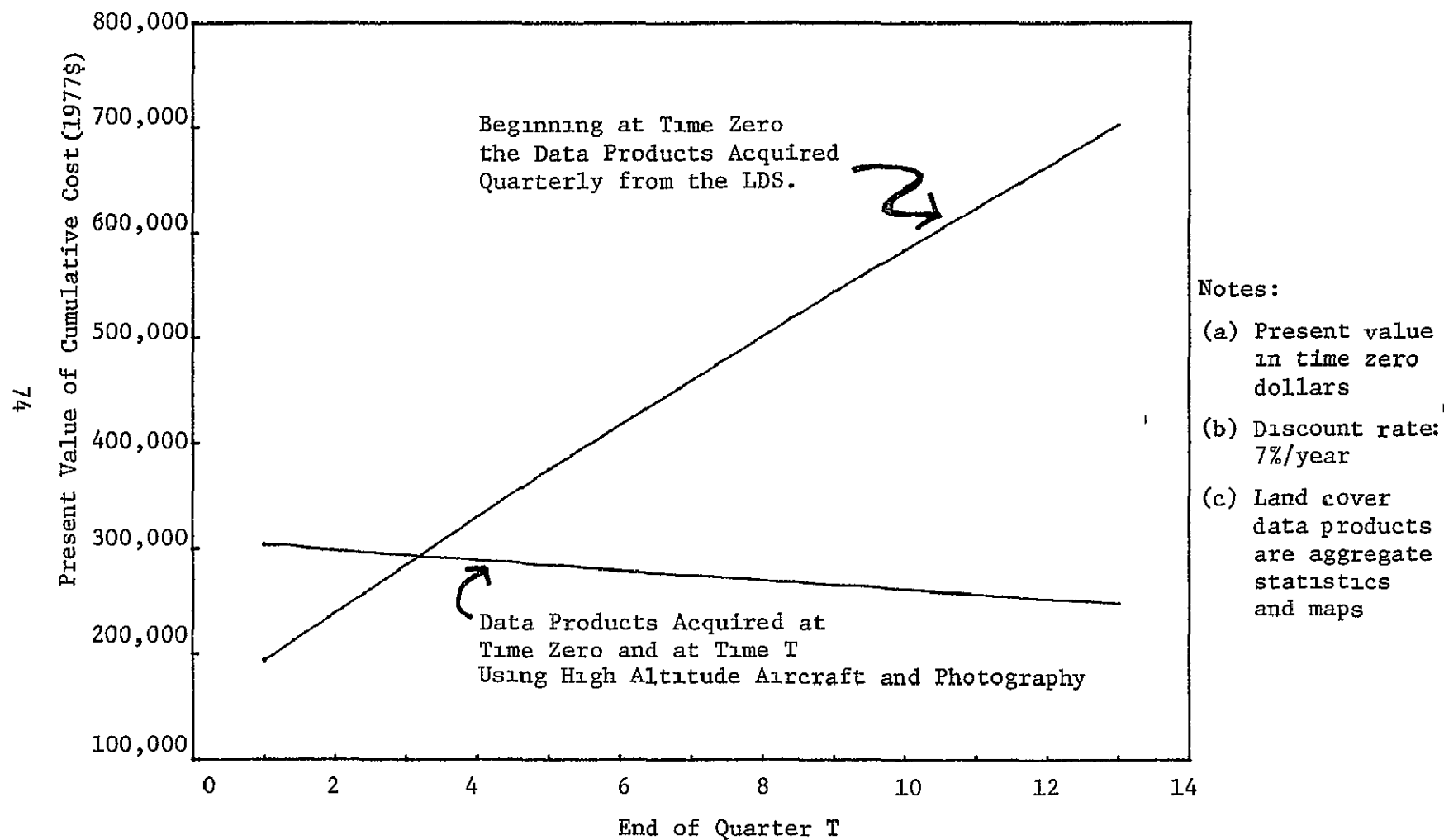


Figure 5-7. Prior to 1981 Quarterly Data Products from LDS Vs. Data Products Every T Quarters Using High Altitude Photography

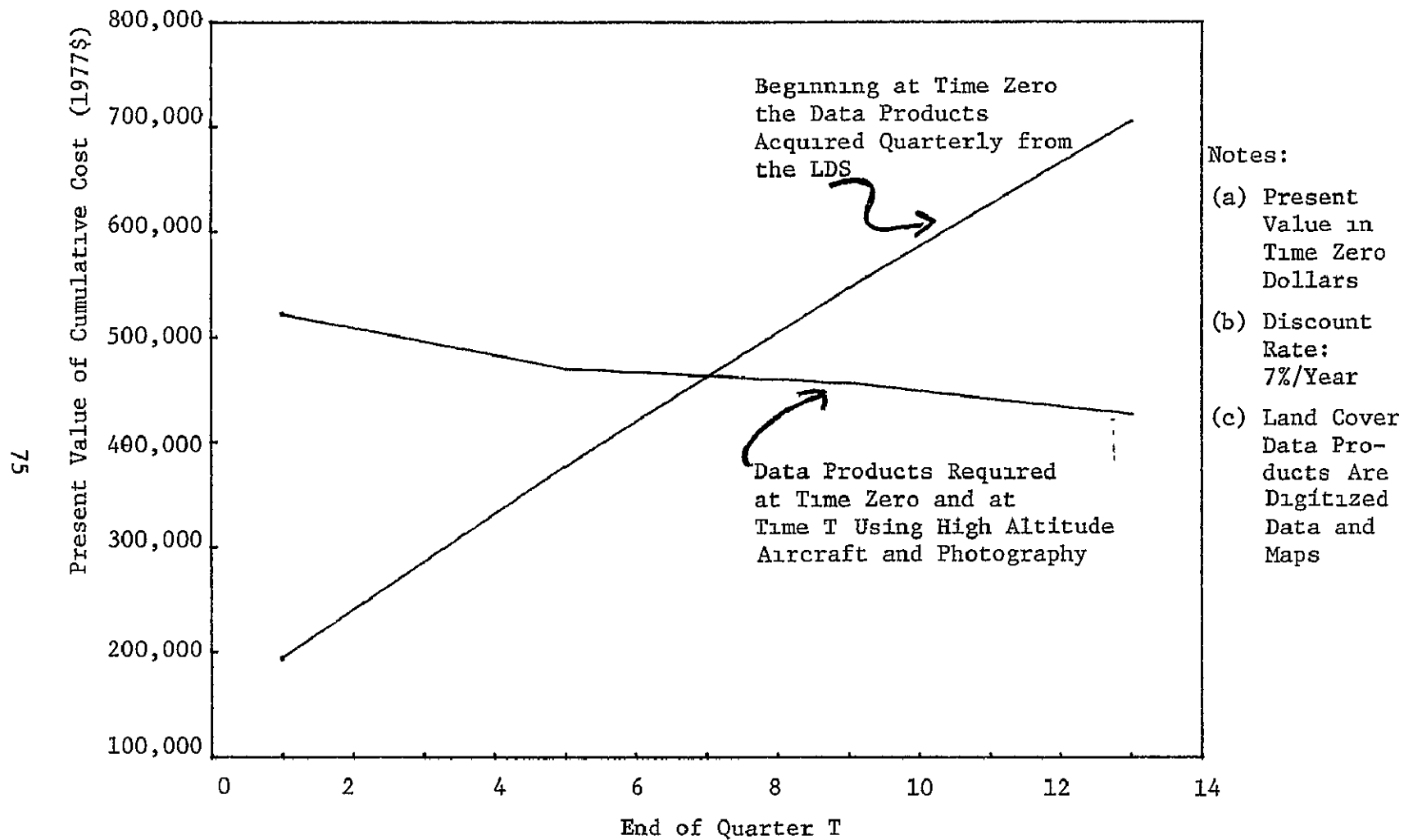


Figure 5-8. 1981 and After Quarterly Data Products from LDS Vs. Data Products Every T Quarters Using High Altitude Photography

SECTION 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The discussions in the preceding sections were oriented toward carrying out the primary objective of this program. to determine the first order costs and benefits of the transfer of NASA remote sensing technology to the State of Georgia via the regional applications program. Based on the various aspects of the study that have been encountered throughout the program and the various levels of detail in the assumptions that have been put forward, the following conclusions are made.

- 1) First order benefits can generally be quantified thus allowing quantitative comparisons of candidate land cover data systems. These benefits can be quantified either in terms of dollars and cents or in non-dollar terms such as delay times, number of landfills, etc. It was generally believed that quantification of second order benefits and social impacts cannot be meaningfully made at this time. While such impacts were discussed with users, they are outside the scope of this study.
- 2) A meaningful dollar evaluation of Landsat can be made by a cost comparison with equally effective data systems. The evaluation is meaningful since the output of alternative data systems or scenarios were taken to be equally effective, thereby permitting a comparison in terms of dollar cost of each system.
- 3) There are currently eight public agencies that make up the major users of Landsat data; these include federal, state and sub-state regional users. Within these agencies, there are twelve distinct agencies that comprise the users.
- 4) Users of Landsat data can be usefully categorized as performing three general functions: planning, permitting, and enforcing. Such categorization allows extrapolation of the results to other states or

regions since it is likely that these functions will be performed regardless of the particular organizational state structure which may exist.

5) For the nominal values of the various parameters, the Landsat system has a net present value of approximated \$9.5 million to Georgia. For reasonable low and high estimates of the parameter values, the net present value ranges from about \$6.5 to \$12.5 million.

6) The value of Landsat data to the State of Georgia is most sensitive to the parameters -- discount rate, digitization cost, and photo acquisition cost. It is relatively insensitive to tape cost and photo interpretation for statistical summary.

7) Under a constrained budget, Landsat could provide digitized land cover information roughly seven times more frequently than could otherwise be obtained. Thus, on one hand while the services derived from Landsat data in comparison to the baseline system has a positive net present value, on the other hand if the budget were constrained, more frequent information could be provided using the Landsat system than otherwise could be obtained.

8) The methodology developed on this program should permit application to other states and extrapolation of results to other regional bases. The techniques used in valuing the cost savings as well as the functions associated with the permitting, planning and enforcing activities have been structured for extrapolation. It is anticipated that the benefits of Landsat to other states and regional programs can be categorized and valued in a similar manner as was done under this program.

6.2 Recommendations

1) The State of Georgia is currently conducting a training program to utilize Landsat data. After the state has gained some operational experience using Landsat data, the desirability of a second iteration of the benefits valuation should be considered. Such an effort would provide an empirical valuation of the Landsat technology transfer

program and provide a validation of the methodology that was used in this investigation.

2) The results and the methodology should be presented to other appropriate agencies to provide them with perhaps another basis for decision-making relative to the use of Landsat derived data.

3) The total impact of the Landsat program for regional transfer of technology includes not only the State of Georgia but other states in the southeastern region. Consideration should be given toward determining the first-order benefits for regional applications.

4) A second analysis should be performed using Landsat 3 and Landsat 4 properly phased to the scenarios. The investigation described herein did not include the improved data products which will be obtained from these satellites.

5) Consideration should be given toward establishing optimal combinations of aircraft/satellite, photograph/multi-spectral scanner derived data, and land cover sampling plans. It is anticipated that some mix of these alternative data acquisition alternatives would be appropriate to a practical inventory system and dissemination of the land cover information.

APPENDIX I

GEORGIA NATURAL RESOURCES
INFORMATION SYSTEM

GEORGIA NATURAL RESOURCES INFORMATION SYSTEM (GNRIS)

Within the Department of Natural Resources, considerable staff expertise and training exists with regard to the use of analytical techniques, both manual and computer-assisted, for natural resource applications. The integration of such techniques and information into a system is recognized as having as a minimum the following pre-requisites:

i) that program managers often have very specific requirements, either legislated or administrative that must be met in order to maintain an effective program. Many of these requirements do not directly address the types of data required in order to administer a program, but rather a performance-standard approach giving parameters on the desired results. Therefore, program managers typically make use of the best existing information which is available if the cost of such information is not prohibitive. This information is then used by professionals on the staff in order to provide a base for determinations or recommendations. Some programs which fall into this description are:

a. the non-point source pollution element (Section 208) of PL92-500.

b. wildlife habitat studies under the Pittman-Robertson Act.

c. permitting activities for sanitary landfills under the Solid Waste Management Act.

d. Environment Impact Statement review through the Federal A-95 procedures.

e. determination of areas for possible acquisition or protection such as historic sites, natural areas, parks, etc.

Other programs operative within the State but focusing on Federal Agencies include:

a. permitting activities under Sec. 404 of PL92-500 by the Army Corps of Engineers, Savannah District, related to dredge and fill.

b. Conservation Needs Inventory by the U.S.D.A., Soil Conservation Service for determining areas of gross erosion, and identification of areas such as wetlands to be addressed in water resources projects.

The existing information used by these agencies in their various activities may cover a broad range, based on the particular activities involved. Some of the more common data sources are:

1. Mapped information from the U. S. Geological Survey:
 - 7 1/2 minute quad sheets
 - 15 minute quad sheets
 - 1:100,000 quads
 - 1:250,000 quads
 - Orthophoto quads
2. Mapped information from State and other agencies.
 - Resource Assessment (DNR/OPR) Soils and Vegetation Maps
 - State Highway maps, 1" = 1 mile, by county
 - Specially prepared maps, such as for river corridor studies or surveys
 - SCS Soils survey map
3. Published information:
 - see Resource Index (DNR/OPR) - a guide to all published natural resource information in Georgia
 - specific, discipline-related material
4. Remote Sensing Information:
 - low-altitude photography - various scales, various film types
 - high-altitude photography - such as U-2 or RB-57 infrared pictures over the coast of Georgia and selected areas
 - Landsat satellite data, both imagery and digital processing
5. Field sampling and verification, such as soil borings, water quality monitoring, etc.

There are other examples which are not included here, but the above list is background information upon which some current activities depend. This should also give some indication as to the types of information which any future system needs to address.

- 11) that program managers will only use the data if it is:
 - reliable
 - reasonable current
 - cost-effective

and understandable to the degree that it directly relates to program needs, and that by using the data, programs over a period of time will either be more efficiently executed, or produce better results, or both. Related to this is the potential opportunity to a program manager using an information system to expand the program's capabilities to include new activities which were previously excluded.

iii) that most natural-resource problems, even those dealt with through state-wide programs, are solved or at least addressed at a fairly site-specific level. Therefore, given limited financial resources and personnel, many agencies must put into priority the areas which they will approach, based on widely varying criteria. Any information system development should recognize that attempting the early establishment of a detailed statewide data base is not necessarily a good idea; in fact, given budgetary cycles, this may be impossible. A structure needs to be established whereby development of a Georgia Natural Resource Information System can reflect the priorities of the agencies involved, yet be flexible over a period of time to include changes in geographic scope and detail.

A current effort in integrating natural resource information for management applications in Georgia takes the form of a demonstration project now underway within the Department of Natural Resources, Office of Planning and Research. The focus of the project in North Fulton County, and the primary issues being addressed are non-point source pollution and sanitary landfill siting. One objective of the study is to determine the feasibility of using computer-assisted methodologies towards these applications. Careful documentation is being kept on the actual time and resources required, and the project has already generated a significant interest among state, federal, and local agencies involved. The computer software being implemented is based on the IMGRID package developed by Harvard University; this package appears very attractive since it is user-oriented and does not require a knowledge of FORTRAN or programming to operate.

The second major effort towards the integration of natural resource information is the TOTP. A combination of State, Federal, and sub-state

regional agencies are participating in this effort by contributing not only financial resources but also substantial field support. Some of the participating agencies are:

- DNR - Environmental Protection Division
 - a. Land Protection Branch
 - b. Water Protection Branch
 - Game and Fish Division
 - Office of Planning and Research
- Govenor's Office of Planning & Budget (OPB)
- Georgia Forestry Commission
- U.S.D.A., Soil Conservation Service
- U. S. Army Corps of Engineers
- U. S. Army, Fort Benning
- State Bureau of Community Affairs
- Coosa & North Georgia Area Planning & Development Commissions

Several of these agencies have expressed not only the need to have information over a period of time, but also interest in combining Landsat data with the types of information being used in the North Fulton demonstration project. The Landsat project and the North Fulton project represent the current status of combining natural resource information for specific management applications at the State Government level.

The future capabilities of a GNRIS will only be limited by the ability of those developing the system to meet the user needs previously described. More definitive information will become available as the Landsat and Demo projects progress on their respective schedules. Both have target dates for initial products by early Fall, 1977.

APPENDIX II

IMPACTS OF NASA REMOTE SENSING TECHNOLOGY ON USER OBJECTIVE

- A. Environmental Protection Division
Land Protection Branch
Surface Mine Land Reclamation
- B. Department of Natural Resources
Environmental Protection Division
Land Protection Branch
Solid Waste Management
- C. Department of Natural Resources
Environmental Protection Division
Water Protection Branch
- D. Georgia Forestry Commission
- E. Georgia Forest Research Council
- F. Area Planning and Development Commissions
- G. Department of Natural Resources
Game and Fish Division
- H. U. S. Army Corps of Engineers

A. ENVIRONMENTAL PROTECTION DIVISION
LAND PROTECTION BRANCH
SURFACE MINE LAND RECLAMATION

Surface mine land reclamation activities are conducted pursuant to regulations regarding surface mine and reclamation of affected land as issued under the Georgia Surface Mining Act of 1968, as amended, and the Executive Reorganization Act of 1972. The primary functions served by this activity are the permitting and monitoring of all surface mining operations within the state. Primarily, these are concerned with the mining of coal, granite, and kaolin. The surface mining of these minerals disturbs the land contours and constitutes a potential for erosion of other surface materials and the pollution of the water system. In order to minimize the potential hazards associated with these mining activities, the land protection branch engages in a permitting function which requires the approval of plans submitted for specific land use in the affected areas. Detailed plans for land reclamation are submitted to the land protection branch to insure that mine lands are adequately restored to an acceptable state after the mining has been completed. A reclamation plan which is deemed acceptable is approved and a bond is posted by the agent conducting the mining activity. Failure to comply with the approved land reclamation plan results in the bond being forfeited; the state then undertakes the land reclamation. Typically, some monitoring of the reclamation process is conducted prior to a final inspection and return of the posted bond for properly restored land.

It is anticipated that Landsat data may be used to supplement present on-site inspection of the reclamation process. It is anticipated further that acid draining, associated with many surface mining activities, may be a problem area in which Landsat data may be effectively used. Acid draining may adversely affect vegetation in the vicinity of the mine site. It may be possible to detect deteriorated vegetation from the Landsat satellite, thus providing a means by which such damage can be minimized through early detection.

Generally, the Landsat remote sensing system is seen to be a potentially useful adjunct to the procedures presently used in the surface mining of the land reclamation activities.

B. DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION
LAND PROTECTION BRANCH
SOLID WASTE MANAGEMENT

The solid waste management activity's main function is in the siting of landfills, sanitary landfills and disposal locations for hazardous materials. Criteria used in approving landfill siting requests are generally intended to control the possible pollution of ground water and air. The location of the water table at a site, the permeability of the soil above the water table and potential for subsoil fire are of prime importance. The damage potential from pollution near a landfill is dependent upon the sites proximity to population centers and water systems and the character of nearby landcover and topography.

The Land Protection Branch has the responsibility of insuring that landfills meet established acceptability standards. Further, the Branch has the responsibility of insuring that waste materials are covered with earth at prescribed intervals.

Landsat data may more efficiently provide some of the site information presently required in waste management though it is not expected to be a complete substitute for information derived from other sources. To a limited extent, Landsat can provide information on the location of major bodies of water, and population centers and the presence of near-surface water tables. The limited ability of Landsat measurements to substitute for on-site measurements suggests its use would be restricted to eliminating some proposed, but clearly unacceptable, landfill sites. It is expected that most proposed landfill sites would require an on-site inspection even if Landsat data were used in a preliminary screening of permit applications.

C. DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION
WATER PROTECTION BRANCH

The Water Protection Branch is currently involved in developing a program to control point and non-point sources of water pollution. The agency views LANDSAT/NRST as an information input to the non-point source pollution control program's development and maintenance. Non-point source pollution is caused by surface water runoff from certain land-use practices in agriculture, silviculture, large-scale construction, mining, waste disposal, and hydrological modification. The present emphasis is on development of a ranking scheme for the State's 198 Water Quality Management Units (WQMU) according to their respective potentials for generating non-point source pollution, this potential is based upon a Unit's topography, soils, climate, land cover, land uses, and land use practices. The ranked indices will serve to establish priorities for problem areas and plan pollution abatement/control efforts. The Water Quality Management Planning Program stipulates that land use assessments should be updated annually; the updates will be used in reassessments of priorities, budget allocations, and to establish current status and future forecasts of pollution potential on a region by region basis.

Though WPB has charter authority to perform a permitting function where necessary, specific areas of permitting are not presently defined. The WPB anticipates that it will not actively become involved in permitting but will rely on voluntary compliance with local ordinances and "best management practice" (BMP) recommendations made to the private sector. In devising BMP recommendations for a given activity in a given WQMU, it has been proposed that simulation modeling be utilized to determine the WQMU's sensitivity through time to various degrees of change in land use/cover. In this way, alternative scenarios for a watershed's development could be postulated and evaluated.

Much of the active permitting done by other agencies such as Land Protection Branch, Corps of Engineers, et. al., affects water quality and, in fact, are controls on non-point source pollution. WPB anticipates that where it deems necessary, it will define/redefine permit approval standards applied by these other agencies.

D. GEORGIA FORESTRY COMMISSION

The forest products industry is one of the largest industries in the State; Georgia has more timberland than any other state except Oregon. The Commission's primary task is to protect the forest resource from fire and epidemic infestations. The speed with which these threats to timber resources can become uncontrollable requires near real-time information upon occurrence. To this end, the Commission maintains a fleet of 36 aircraft and a large number of rangers. Three aerial surveys are flown during each warm-weather season for purposes of disease detection and to photograph timberland. Each survey represents a 25% sample. The criterion for a "worse than endemic" disease state is "more than one multi-tree spot per 1000 acre host type," the infestation can presently become as large as 10 acres before it can be detected. Aerial photos of every Georgia county are kept up to date via the 25% sample. In addition to these, the Commission obtains winter-flown aerial survey photos of the entire state every four years from USDA/ASCS in order to determine forest types, stratified by percentage pine (89% of the timber cut in Georgia is pine).

The Commission provides a forest management planning service for private land owners; the service is performed on the district level and is limited to four man-days per year for any land owner. The owner woodlands are assessed and best management practice recommendations are made to assuring the owner of an optimal economic return. About 3800 of these plans are prepared per year.

The Commission is concerned about alternative land use. Agriculture impacts upon future forest potentials, land ownership patterns are also of interest since they bear a relationship with actual forest size and management practices. Adequate information on land use and ownership categories are presently unavailable.

It is predicted that the demand on Georgia's wood supply will double by 1990. In the southern portion of the state, harvest rate already exceeds growth rate. This has led to present considerations of regulating harvest and industry development to prevent unwise depletion of the forest land through uncoordinated private interests.

E. GEORGIA FOREST RESEARCH COUNCIL

The Council's role as a state agency is to address the problems of forest resource development by identifying forest research needs, providing funding for high priority areas, and disseminating research findings. Most research in the past has been devoted to forest protection, silvicultural practices, and genetic tree improvement. There is mounting concern to begin research into regulatory incentives for forest economy, forest inventory control, and long-term land use impacts on forestry. (The silvicultural cycle is 15 ~ 30 years, depending on management intensity, long-term impacts are especially critical) The information base needed to perform such long term, state-wide research is as yet unavailable. LANDSAT/NRST is viewed as a potentially valuable input in the acquisition and maintenance of such an information base

F. AREA PLANNING AND DEVELOPMENT COMMISSIONS

Area Planning and Development Commissions throughout the State act in the advisory capacity to other governmental agencies on the city, county and regional level. Their charter is to assist in formulating policies that foster area wide development. The Commissions themselves make no decisions but provide information for decisions made in other agencies. Generally, their recommendations involve combining demographic data and land use data to determine how much land will be required and where, for different purposes. The kinds of decisions the Commissions impact are water and sewage system construction, the design of collection systems for solid waste, establishing fire districts (locating fire stations). The methodology employed in formulating recommendations focuses on the present and projected demographic characteristics of an area.

They make use of the "highway corridor concept" in projecting demographic/industrial growth. Growth generally takes place along major transportation routes. An issue the Commissions deal with is whether this growth is to be distributed or localized along a highway corridor. The sizing of water lines and location of treatment plants, for example, would differ between the two growth patterns.

The APDC's feel Landsat data would be useful and anticipate acquiring an initial summer and winter scene then possible annual updates. Presently they have a target of revising their data base every 5 years. The Commissions envision no measurable direct benefit from Landsat. The expectation is that they would have more confidence in, and support for, future recommendations. Neither the type nor quality of recommendations are likely to be influenced by Landsat. The map format of Landsat is a feature which would enhance the effectiveness of the written reports and recommendations made by the Planning and Development Commissions.

Regional development to a large extent is felt to depend on local taxes. Tax valuation policies based on land use are presently being considered as a mechanism by which the State could influence future growth patterns. To

be practical on a regional basis, such a tax scheme would require that timely information on land use changes be available. The information from Landsat, while in fact land cover, is expected to be readily correlated to the land use categories that would be employed in tax valuation/re-evaluation schemes.

G. DEPARTMENT OF NATURAL RESOURCES
GAME AND FISH DIVISION

The Game and Fish Division has the responsibility for wildlife management within the State. Wildlife inventories are affected by the amount of suitable habitat, productivity and depletion rates due to hunting and fishing. The controls exercised by the Game and Fish Division are through establishing wildlife preserves, moving wildlife/stocking, and regulating hunting and fishing within various regions.

The primary role envisioned for LANDSAT data is in providing area wide information on land cover suitable to various wildlife. The correlation between land cover and the habitability by wildlife should enable the State to region-by-region control wildlife populations thus more effectively avoiding local overpopulation and local depletion.

LANDSAT data might further be used in developing environmental impact statements required for major construction projects. Many such projects can potentially produce major changes in wildlife habitats. Knowledge of specific wildlife habitats could enable damage to wildlife resources to be avoided/mitigated.

H U. S. ARMY CORPS OF ENGINEERS

Among the many functions of the Corps of Engineers are flood control, beach erosion control, the generation of maps and information on flood plains and regulating dredge and fill operations affecting wetlands and navigable water. The Corps' performances of the first three of these functions can potentially be improved with the use of Landsat data. Current information on changes in land cover can be obtained for purposes of allocating Corps' resources and providing timely information on flood plain conditions.

The fourth function, regulating dredge and fill operations, can potentially be done more efficiently using the land cover information available from Landsat. Beyond aiding in determining in advance the potential erosion caused by dredging and fill operations, Landsat data can be used in detecting any changes in wetland size indicative of dredging and fill problems. Used in the detection mode, Landsat can provide the information necessary to practically apply performance standards to dredge and fill operations rather than relying on before-the-fact, limited-area terrain standards. Permitting activities based on performance standards as well as terrain standards should make the Corps' regulatory process more effective in safeguarding the State's water and wetland resources.

APPENDIX III

MODELS OF THE BENEFITS DERIVED FROM THE LANDSAT DATA SYSTEM

APPENDIX III
MODELS OF THE BENEFITS DERIVED FROM THE
LANDSAT DATA SYSTEM

The results of the user survey could be synthesized to address the benefits derived from Landsat in various ways. The alternatives considered were (1) essentially treat every user separately, that is, in fact no aggregation or (2) to use a functional classification scheme to group users into groups of general land cover requirements. In this study, the functional classification scheme was chosen for purposes of consolidating the user survey results into a more useful form. The reasons that functional classification was chosen are three. First, the individual user responses led to the observation of the direct relationship existing between user function, data product frequency requirements and the data product format requirements. Secondly, a functional classification of users is desirable in that the agency functions are expected to be common to other geographical authorities, that is, to other states on a regional basis and on a nationwide basis. The third reason which derives largely from the second was that the study results had been more readily generalized than if they were based on a specific institutional structure reflected in the user community. That is, the organizational relationship among the users may differ from locale to locale but the functional responsibilities of the user community might be expected to be common across any geographical area. The Landsat data system's benefit classification related public agency functions to land cover. This process entails defining two general categories or objectives served by the user community.

Protecting the Public and Public Resources

Supporting this objective are functions of program research and development, i.e., planning, program permitting and program implementation or monitoring and enforcement. Aside from these preventive or protective

objectives of the state agencies, the second category, or second broad objective of public agencies can be defined.

Supporting Economic Development

Within this category three general functions performed by different agencies were identified. First, fostering the balanced use of state resources. The character of this function is to direct the use of the natural resources of the State in such a way as to result in the most desirable distribution of land among alternative uses. A second function supporting economic development within the State is that of enhancing land productivity for the given land use. A third function supporting economic development might be described as that of eliminating barriers to regional development. This essentially involves a public investments to encourage, foster, or enhance economic development which would otherwise take place more slowly or in a much less desirable manner.

In the functions of supporting balanced land use and enhancing land productivity, the benefits derived from the Landsat Data System exhibit a largely qualitative character. That is, having access to the better land cover information available from the LDS, decision makers should be able to make, in some sense of the word, "better" operating decisions. Land use and land productivity may well change as a result of having the LDS but it does not appear possible to do any meaningful quantification or modeling of such ill-defined eventualities. These two functional improvements, benefits, derived from the LDS while real must necessarily be subjectively considered by proponents of the Landsat Data System.

The remaining benefit classifications reduce to three functional areas; planning, permitting, and monitoring and enforcement. With respect to the planning function shared by many users, the Landsat Data System should allow more reliable forecasts which in turn might generally enable better planned land use. In the permitting function which similarly lies in the domain of several user agencies within the State of Georgia, the land cover information from Landsat should allow a reduction in the need for on-sight

inspection where this inspection entails determination of land cover characteristics. The benefits available from Landsat in an enforcement function are essentially that the land cover data should lead to an earlier detection of permit violations or hazards or other problem areas which are reflected in local land cover. This early detection is in fact a benefit inasmuch as the cost to remedy a violation or problems might typically be expected to be reduced or similarly the damage done by some violation or land cover problem might be less than otherwise would have been the case. Models were developed based on these general characterizations of the benefits realized from Landsat data products.

The Planning Function

The general objective served by planning within the State of Georgia is to make more effective use of state funds. In the short run, this is associated usually with the allocation of annual budget in the various state agencies. Landsat may provide input information into this budget allocation process which is needed for efficient planning. This input information may be more information than is presently available from the planning process. It may be in some sense equivalent information to that presently being used but the Landsat information would presumably be available at a lower cost than is the present information. The long run aspects of planning are to provide for future needs of the state. Long run planning in general requires some forecasting in order to project future needs and resource availability. It is in this forecasting effort that Landsat data might be used advantageously. Forecasts available with the better data from the Landsat Data System are expected to be more reliable and more accurate. To illustrate the advantages derived from Landsat in producing data based forecasts, the following discussion of the planning function and forecasting using Landsat data products is presented.

Most of the planning done by the State is based on gradual changes in some phenomena such as seen in living patterns, expansion or contraction of farming activity in an area, etc. The various readily available statistical techniques of forecasting and projecting trends include regression analyses, exponential smoothing, and others. All these forecasting techniques are limited by the quality of the input data - its accuracy, its completeness, its age.

Assume data describing a phenomenon of interest is available every T years. This might reflect the 10 year census cycle, or some periodic assessment of a natural resource inventory. Assume further that the state relies on the T year for forecast to conduct its activities and make investment decisions between successive data collections. The question which is of interest is does having data from Landsat at more frequency intervals, every τ years where $\tau < T$, result in significantly better forecasts.

In producing an estimate of a parameter by statistical techniques, the "goodness" or "tightness" of the estimate is represented by a confidence interval. The confidence interval is here defined as some multiple of the parameter's variability and provides estimates of the upper and lower error limits. The level of confidence is commonly expressed as a percentage: the probability that the parameter's true value lies within the error limits (the standard notation for this probability is $(1-\alpha)$ where α is the probability that the true value lies outside the confidence interval; thus in general we have $100(1-\alpha)\%$ confidence in an estimate). The narrower are these limits for a specified confidence level, the more reliable is the estimated or expected value.

Suppose that the time series of observations concerning a phenomenon of interest X_t can be represented by the general model

$$X_t = \sum_{i=1}^k b_i z_i(t) + E_t$$

where b_i is the coefficient of the i^{th} term in the model and the independent variables $z_i(t)$ are some specified functions of time. Use of this model

assumes that the observations are taken at equally spaced time intervals. If we assume that the random error E_t are normal independently distributed random variables with mean 0 and variance σ_E^2 , then the b_1 can be estimated by a least squares fit of the model to the historical data (regression analysis, exponential smoothing, etc.) which assures that the model yields statistically unbiased forecasts and enables the calculation of confidence intervals. For illustration, consider the simplest case where the model for the phenomenon of interest is linear with time, where $k=2$ and $z_1(t) = t^{1=1}$ (i.e., $z_1(t) = 1$ and $z_2(t) = t$):

$$X_t = b_1 + b_2 t + E_t.$$

Having obtained the parameter estimates $(\hat{b}_1, \hat{b}_2)$, the forecast made at time T for ℓ periods ahead is the expected value of $X_{T+\ell}$, or

$$X_{T+\ell} = \hat{b}_1 + \hat{b}_2 (T+\ell)$$

since the expected value of $E_{T+\ell}$ is always 0. The estimates $\hat{b}_1$ and $\hat{b}_2$ are based upon the actual historical data observations taken at equally spaced time intervals. If we suppose that there exist N such observations, then the $100(1-\alpha)\%$ confidence intervals for the parameter estimates are

$$\hat{b}_1 \pm [t_{\alpha/2, N-2}] \hat{\sigma}_E \left[\frac{4N+2}{N^2-N} \right]^{1/2} \quad \text{and}$$

$$\hat{b}_2 \pm [t_{\alpha/2, N-2}] \hat{\sigma}_E \left[\frac{12}{N^2-N} \right]^{1/2},$$

where $[t_{\alpha/2, N-2}]$ is the percentage point of the t- distribution with N-2 degrees of freedom at level $\alpha/2$ (the t- distribution is used because the true error variance, σ_E^2 , is unknown and must be estimated, $\hat{\sigma}_E^2$). Now an interval estimate for the forecast itself at time $T+l$ can be derived. This prediction interval is a function of the number of periods ahead being forecast, l , as well as the confidence intervals of the current estimates. In general, the prediction interval widens as l increases (see Figure III-1) and can be shown to be

$$\hat{X}_{T+l} \pm [t_{\alpha/2, N-2}] \hat{\sigma}_E \left[1 + \frac{2}{N-3} [(2N-1)(N-1) + 6l(N+l-1)] \right]^{1/2}.$$

The relationship between the width of the confidence/prediction intervals and the number of available data points for estimation are illustrated in the example. Similar results are obtained for more complex versions of the above general method.

Any classical forecasting technique explicitly assumes that the underlying process which generates the variable of interest, X_t , will not change during the forecast period l . If the underlying process does change, then the subsequent observed realizations X_{T+t} will deviate from the anticipated realizations $\hat{X}_{T+t}$ in some consistent or systematic manner; for example, the actual realizations might begin to consistently lie outside the prediction interval, indicating that the current model formulation needs modification (perhaps by adding new terms to the model and at least by obtaining new estimates of the b_1). Obviously, the shorter the interval between observations the sooner a change in the underlying process can be recognized and the forecasts modified accordingly.

In summation, benefits arise in two areas from the use of Landsat data in the planning function. (1) more reliable forecasts based upon an increased number of data acquisitions, and (2) a sooner adaptation to changing patterns based upon a shorter interval between observations.

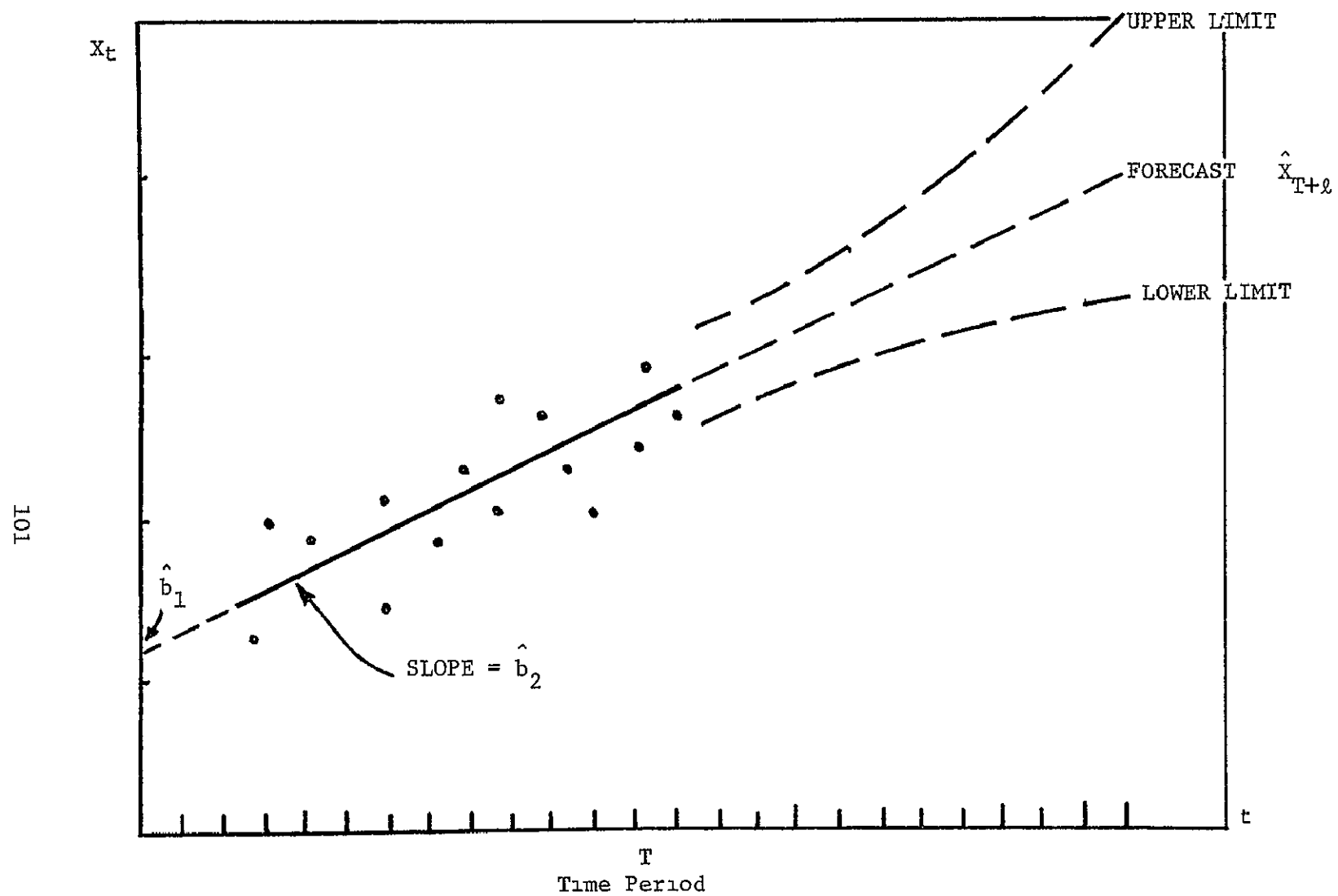


Figure III-1. Forecasts and Prediction Intervals

Underlying any data forecasting technique is the assumption that the past portend something about the future, i.e., there is some perhaps ill defined relationship which characterizes or dictates a phenomena of interest. Assuming this condition is satisfied, it may be expected that with the Landsat Data System, the benefits will be realized by virtue of a larger amount of land cover information being available and also because land cover information will have more frequent update. To precisely identify the benefits derived from this enhanced forecasting capability it would be necessary to find answers to questions regarding how much data would actually be used and also what decisions made within the state agencies would change. The decision changes of interest may be differences in the kinds of decisions, differences in the timing of decisions, possibly merely differences in the decision makers confidence in his decision. To indicate the magnitude of the enhanced forecasting capability available from Landsat consider the following example which illustrates the impact of data quantity in producing forecasts, and associated error limits, for an approaching "target" time period. For pedagogical reasons attention will be focused on the simple linear forecast model discussed above. The time series of data shown given in Table III-1 and shown in Figure III-2 was generated using the model

$$X_t = 20 + 3.333t + E_t$$

where E_t is a normal random variable with mean 0 and standard deviation 5. Let X_t denote say actual acreage in a particular row crop and $\hat{X}_t$ a forecast thereof. Note that as the target time period is approached, the prediction interval for $\hat{X}_t$ will decrease due to smaller lead time l as well as due to larger quantity of data N . The important aspect in this example is the effect of N .

TABLE III-1
HYPOTHETICAL DATA FOR THE FORECASTING MODEL

I-Annual Data		II-Semiannual Data			
t	X_t	t	X_t	t	X_t
0	17.2	0	17.2	3.0	38.3
1	13.0	0.5	26.7	3.5	22.2
2	23.1	1.0	13.0	4.0	44.2
3	38.3	1.5	24.4	4.5	35.3
4	44.2	2.0	23.1	5.0	37.5
5	37.5	2.5	28.6		

Assume the current time is year $T=5$, that no data are available for years preceding time zero and that a forecast for a target year $T=9$ is updated annually. Consider two situations: the first in which observations X_t are taken annually and the second in which observations are taken semi-annually. At $t=5$, the available data in each of these two situations are as follows. The initial estimates of the b_1 and for X_9 , from simple linear regression, and the associated 95% intervals are

$$\begin{array}{c} \text{I} \\ \hat{b}_1 = 13.9 \pm 12.9 \end{array}$$

$$\hat{b}_2 = 6.0 \pm 8.8$$

$$\hat{X}_9 = 67.9 \pm 26.2$$

$$(N=6, \ell=4)$$

$$\begin{array}{c} \text{II} \\ \hat{b}'_1 = 17.3 \pm 7.3 \end{array}$$

$$\hat{b}'_2 = 4.4 \pm 3.7$$

$$\hat{X}'_9 = 56.6 \pm 15.2$$

$$(N=11, \ell=4)$$

where the primes denote estimates based on semiannual data. At the next iteration, $T=6$, additional data are:

$$\begin{array}{c} \text{I} \\ t=6 \quad X_6 = 30.2 \end{array}$$

$$\begin{array}{c} \text{II} \\ t=5.5 \quad X_{5.5}=44.8, t=6 \quad X_6=30.2 \end{array}$$

and the model parameters are updated by refitting the model to the data, thus obtaining.

$$\begin{array}{c} \text{I} \\ \hat{b}_1 = 17.4 \pm 10.9 \end{array}$$

$$\hat{b}_2 = 3.9 \pm 6.86$$

$$\hat{X}_9 = 52.5 \pm 20.1$$

$$(N=7, \ell=3)$$

$$\begin{array}{c} \text{II} \\ \hat{b}'_1 = 18.6 \pm 6.47 \end{array}$$

$$\hat{b}'_2 = 3.7 \pm 3.05$$

$$\hat{X}'_9 = 51.7 \pm 13.7$$

$$(N=13, \ell=3)$$

Similarly:

Phenomena of Interest
(e.g., Thousands of Acres in Row Crops in a particular County)

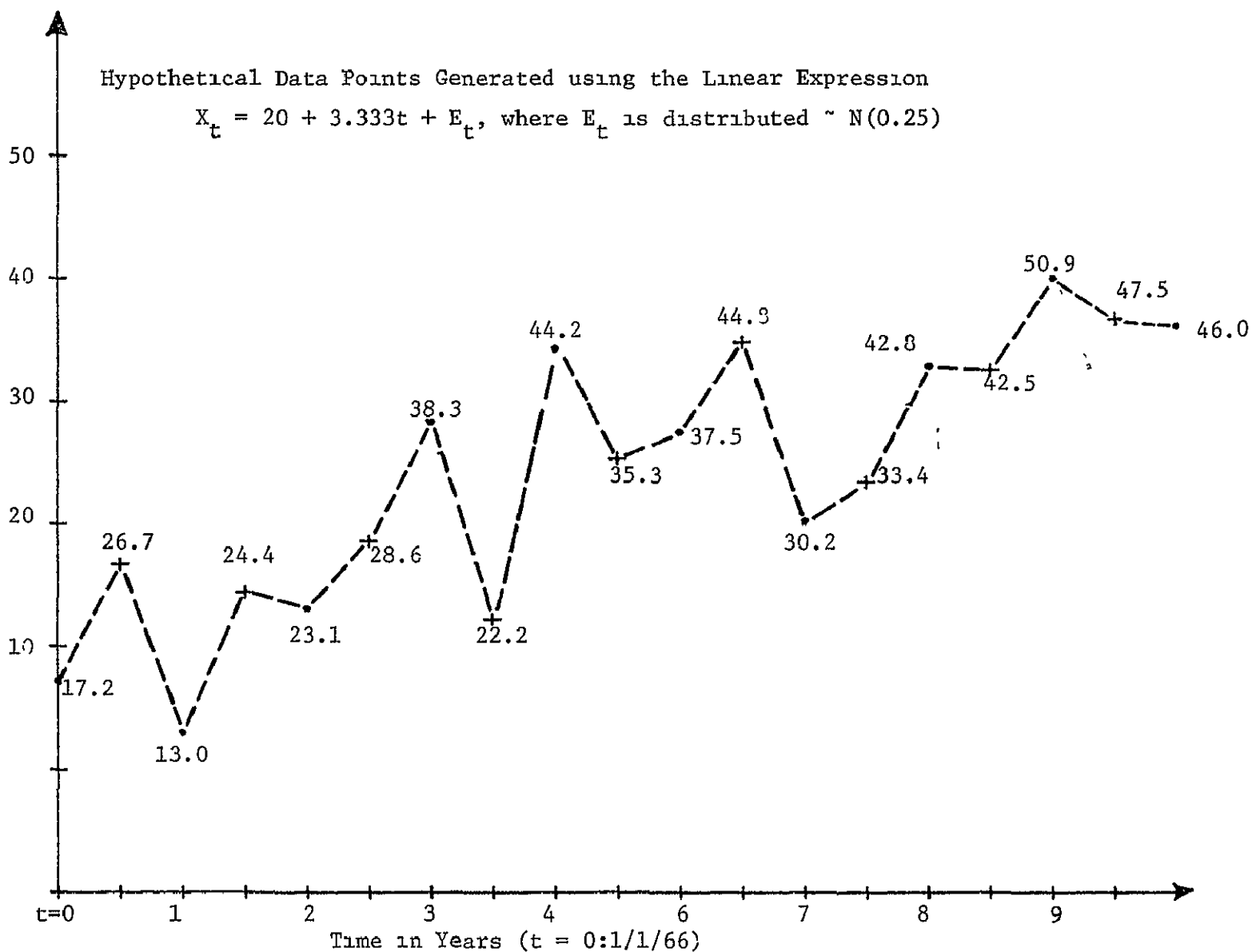


Figure III-2. First Order Benefits

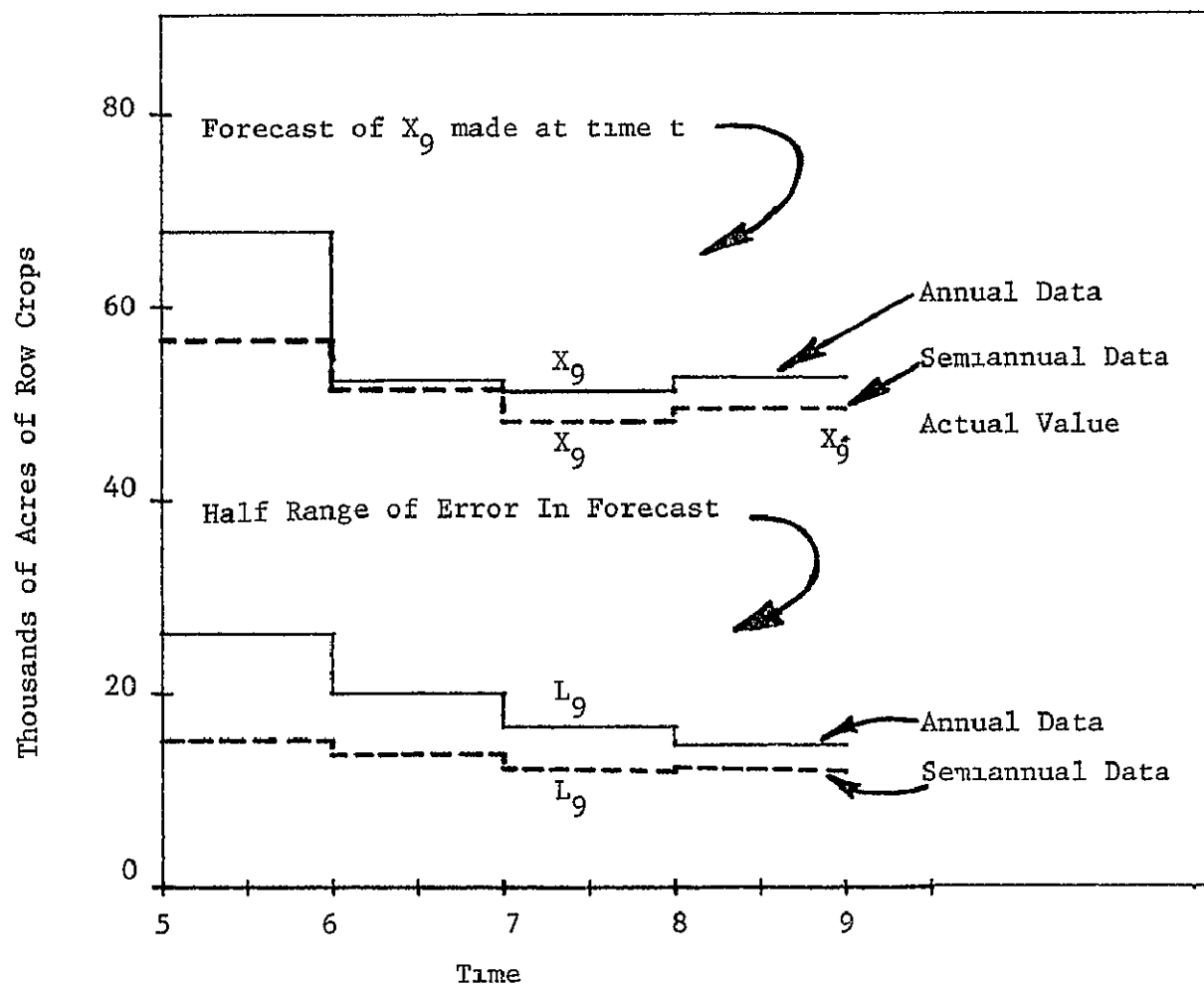
at T=7	I	II
	$\hat{b}_1 = 17.7 \pm 9.53$	$\hat{b}'_1 = 19.5 \pm$
	$\hat{b}_2 = 3.7 \pm 5.66$	$\hat{b}'_2 = 3.2 \pm$
	$\hat{X}_9 = 51.4 \pm 16.6$	$\hat{X}'_9 = 48.4 \pm 12.4$
	(N=8, $\ell=2$)	(N=15, $\ell=2$)
and at T=8	I	II
	$\hat{b}_1 = 17.2 \pm 8.60$	$\hat{b}'_1 = 19.1 \pm 5.40$
	$\hat{b}_2 = 4.0 \pm 4.82$	$\hat{b}'_2 = 3.4 \pm 2.24$
	$\hat{X}_9 = 52.8 \pm 14.7$	$\hat{X}'_9 = 49.6 \pm 11.9$
	(N=9, $\ell=1$)	(N=17, $\ell=1$)

Figure III-3 summarizes the above results comparing the forecast values made at time, T=5, 6, 7, 8. The figure also shows the relative magnitudes of the prediction interval for the respective forecast (i.e., the forecast and interval is represented as $\hat{X}_9 \pm L_9$ or $\hat{X}'_9 \pm L'_9$. On the vertical axis is plotted thousands of acres of row crops in cultivation; on the horizontal axis is time and in years. At time 5, the forecast was made of the acres of row crops that were in production at time 9. In the diagram, the datum X_9 indicates the actual acreage that will be in row crops at time 9. Plotted in the upper two curves are the forecasts made of X_9 . These forecasts of X_9 are made at various points in time. Consider the forecast made at time 5. The forecast shown in the solid line of roughly 68,000 acres in production compared not very closely with what actually is cultivated at time 9, i.e., 43.5 thousand acres of row crops. Alternatively at time 5, a forecast was made using semiannual data as opposed to the annual data. Using semiannual

historical data for the past five years which effectively means twice as many data points as had been used above. The forecast for X_9 was 57 thousand acres. This is a considerably more accurate forecast than had been available using annual data. Indexing time to $t=6$, the forecast are revised; new values using both annual and semiannual data can be found. Using the linear model the forecasting using the annual data was roughly 52,500 acres of row crop; using the semiannual data it was 51,700 acres of row crop. The forecasts were revised at the end of each time period. It should be noted that comparing the two upper curves in the figure that the dotted line for forecast generated using semiannual data is consistently more accurate than the solid line forecast which depicts forecasts generated using half as much data or data on an annual basis. In the lower portion of Figure III-3 the half range of the error for the 95% confidence level is plotted. Again we note that each point in time the forecast error was computed for both semiannual data and annual data forecasts. It should be noted again that the dotted line, the error associated with the semiannual data is far less than than associated annual data. In summary, it is concluded that a semiannual update, or more generally a more frequent information update, allows more accurate forecasts to be obtained and it also increases the confidence that can be placed in the forecast. This generalization applies beyond the context of the particular model applied and the particular data used in the illustration.

The Permitting Function

The permitting function is one of the mechanisms the State and Federal Government uses to control the activities of individuals or agencies which have potentially damaging effects on the general public. The activities of interest in the present study are those related to land use and land cover. Certain land uses in particular circumstances can lead to high social costs in terms of air and water pollution and their attendant consequences on the safety and health of the public.



Notes:

(A) Linear Forecasting Model

$$X_t = B_1 + B_2t + E_t$$

- (b) Random hypothetical data
- (c) Normally distributed error
- (d) Forecasting confidence level 95%

Figure III-3. First Order Benefits: Illustration of Improved Forecasting Capability for Planning Purposes When More Data is Available

The permitting function is a passive function. It does not involve selecting sites but rather entails evaluating sites which have been proposed by parties applying for permits. This passive mode of operation is one which minimizes intrusion on the freedom of choice of applicants while still safeguarding the public interest.

Typically an applicant selects a site for conducting an activity in such a way that his particular interests are best served. Examples of criteria an applicant might reasonably apply in site selection are land cost, distance to a service area, accessibility from major transportation arteries, tax base implications, etc. Having selected a site for an activity, an applicant makes a formal request to the permitting authority for site approval. The permitting authority applies minimum standards and experience based judgement to determine if a proposal site is acceptable. The standards applied in approving a site do not necessarily reflect the criteria applied in selecting a site; in fact, the standards are usually at odds with the applicants site selection criteria. The inherent divergence of interests requires that each permit application be checked carefully.

When the permitting function addresses land uses which are related to the land cover, some savings may be available from using Landsat data. If Landsat can provide accurate, reliable information on land use near a proposed site, some presently incurred site inspection cost can be avoided. Further, for those applications which can be rejected just on the basis of local land cover, the cost of a trip to the site could be avoided. The benefits derived from Landsat, then, are dependent upon the rate at which permit applications are received, the cost of an on-site inspection of local land cover, the application rejection rate where rejection is based on local land cover, and the cost to send an inspection team out to a proposed site.

These savings may reflect dollars accruing to either the applicant or the State depending upon the fee structure established for obtaining permits. Regardless of how the savings are apportioned, a real savings in resources will be realized in the process of arriving at an approved site.

To construct a mathematical expression for the value of Landsat data in performing a permitting function, some notation will be needed. For ease of reference, this notation is consolidated in the list below.

Notation

- A = average arrival rate in permit requests/unit time
- C_G = cost to inspect a site for general characteristics which would alternatively be obtained using Landsat
- C_T = average cost to send an inspection team to a site
- d = the discount rate
- PVS = present value of the stream of savings associated with a more efficient permitting procedure for a permitting agency
- PVSPF = present value of Landsat per level of permitting activity (level of permitting activity is expressed in permits processed per unit time)
- R_G = application rejection ratio, the proportion of applications which are rejected on the basis of general site characteristics (characteristics which could be determined from Landsat)
- S = savings rate in dollars/unit time
- S_{NI} = savings rate for savings derived from not having to make an on-site inspection
- S_{EI} = savings rate for savings derived from more efficient on-site inspection

Assume that normally a site is inspected for its general characteristics and then for its specific characteristics such as might be determined from soil borings, etc. Assume further that Landsat data could provide information on the general site characteristics.

The quantity AR_G is the number of requests/unit time which are rejected because of substandard general site characteristics. For each of these, having processed Landsat data would allow the rejection to have been made without any on-site inspection. These savings per unit time are

$$S_{NI} = AR_G (C_T + C_G)$$

The remaining permit requests, $A(1-R_G)$, would still require field inspections. If Landsat data were available, these site inspections would not entail inspection of the general site characteristics. These savings per unit time

$$S_{EI} = A(1-R_G) C_G$$

The total savings per unit time is

$$S = S_{NI} + S_{EI}$$

The present value of these savings per unit realized over the indefinite future is

$$PVS = \sum_{t=1}^{\infty} \frac{S}{(1+d)^t} = \frac{S}{d}$$

Substituting for S yields

$$PVS = \frac{A}{d} (C_G + R_G C_T)$$

This expression describes the net present value of the benefits derived from using Landsat data in the permit-issuing function.

Applying the Model

Various State and Federal agencies who are potential users of processed Landsat data perform a permit issuing function. For a sample of these, the users interviewed in the study including the Army Corps of Engineers, Land Protection Branch of the Georgia Department of Natural Resources and others, data will be collected from each on their particular parameter values for A , C_G , R_G , and C_T . A value of d , the social discount rate, will be estimated separately. Values of PVS will be computed for each user and added

to get a total present value. Dividing this by the total application rate gives a measure of the present value of the savings derived from Landsat which is associated with the permitting function, PVSPF

$$PVSPF = \frac{\sum_1 A_1 (C_{G_1} + R_{G_1} C_{T_1})}{d \sum_1 A_1}$$

where 1 is an index denoting the users in the sample. PVSPF is an estimate of the average savings per unit application request rate. The value of PVSPF can be multiplied by the level of permitting activity within a geographic area to give an estimate of the present value of Landsat in the permit issuing function. In this form, savings can readily be estimated for different geographic units and for potentially new permitting requirements such as for clear cropping timber.

The Monitoring Function

Various user agencies have regulation enforcement responsibilities. This generally requires that they monitor conditions within a given area. This monitoring may be to detect potential pollution problems associated with large exposed land areas, or detection of permit violations or for various other purposes. Generally monitoring is done to detect "problems" which may be of various character or origin. Monitoring may entail periodic inspection of a set of known sites or it may involve a general area of coverage. Assume there is no set pattern in the way problem areas arise. That is, they are equally likely to occur anywhere at any point in time, or equivalently, problems arise randomly. If we assume the damage caused by a problem is related to the length of time it goes undetected, some benefits accrue to improving the detection process. Examples of such damage-time relationships

are erosion of soil, size of a contaminated area and the cost to remedy a problem. To measure the benefits derived from using Landsat data in the monitoring function, the first step will be to determine how much more quickly it allows problems to be detected than is presently possible. Figure III-4 shows a queuing model designed to compute the life span of a problem, the length of time a problem goes undetected. Our interest is focused on the detection capabilities which, in the model, corresponds to a stochastic queue discipline.

The Queuing Model (Following the details of the model construction is not necessary to a general appreciation of its final form).

Assume the detection process employs M agents each having a probability of p of finding an undetected problem in a time interval of length Δt . Let n denote the number of undetected problems which exist at some point in time. The probability of detecting any problem in the time interval Δt is proportional to the number of inspection agents, M , the number of existing problems, n , and the length of the time interval Δt . Define an event as either the arrival of a new problem or the detection of an existing problem. The interval Δt is to be taken small enough so that the probability of two or more events occurring in Δt is negligibly small. The following expressions stem directly from the above assumptions.

- (1) The probability of a single problem arising in the interval Δt is $\lambda \Delta t$ given $n < s$.
- (2) The probability of no problem arising in the interval Δt is $1 - \lambda \Delta t$.
- (3) The probability of one existing problem being detected in the interval Δt is $Mnp\Delta t$.
- (4) The probability of none of the existing problems being detected in the interval Δt is $1 - Mnp\Delta t$.

Let $P_n(t)$ denote the probability of n undetected problems existing at time t . The probability of n undetected problems existing at time $t + \Delta t$ is

$$P_n(t + \Delta t) = P_{n-1}(t)p_{+1} + P_n(t)p_0 + P_{n+1}(t)p_{-1}$$

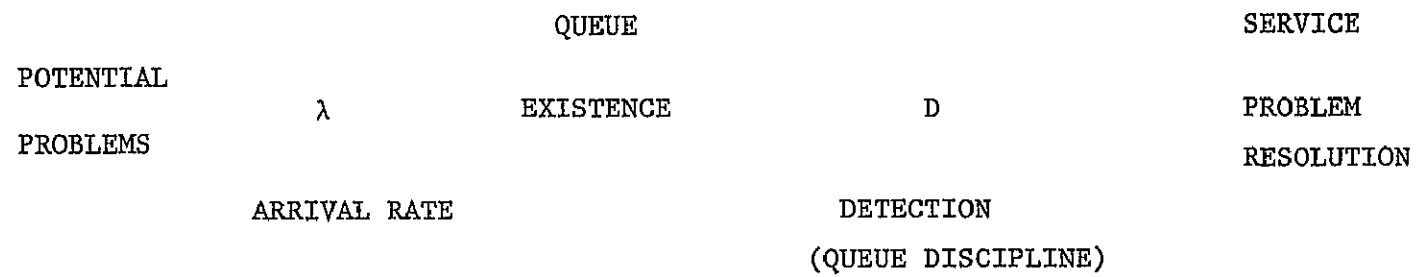


Figure III-4. Queuing Model of the Monitoring Function

where.

P_{+1} , the probability of an increase in the number of undetected problem over the interval Δt , is

$$p_{+1} = (\lambda \Delta t)(1 - Mnp \Delta t),$$

one problem arising, none being detected.

p_0 , the probability of no change in the number of undetected problems in the interval Δt , is

$$p_0 = (1 - \lambda \Delta t)(1 - Mnp \Delta t),$$

no problem arising and none being detected.

p_{-1} , the probability of a decrease in the number of undetected problems in the interval Δt , is

$$p_{-1} = (1 - \lambda \Delta t)(Mnp \Delta t)$$

no problem arising and one being detected. Substituting the appropriately indexed values of p_{+1} , p_0 and p_{-1} into the expression for $P_n(t + \Delta t)$ yields

$$\begin{aligned} P_n(t + \Delta t) = & P_{n-1}(t) [\lambda - \lambda Mnp \Delta t] \Delta t \\ & + P_n(t) + P_n(t) [-\lambda - Mnp + \lambda Mnp \Delta t] \Delta t \\ & + P_{n+1}(t) [(n+1)Mp - (n+1)\lambda Mp \Delta t] \Delta t \end{aligned}$$

Rearranging terms yields

$$\begin{aligned} \frac{P_n(t + \Delta t) - P_n(t)}{\Delta t} = & P_{n-1}(t) [\lambda - \lambda Mnp \Delta t] + \\ & + P_n(t) [-\lambda - Mnp + \lambda Mnp \Delta t] + \\ & P_{n+1}(t) [(n+1)Mp - (n+1)\lambda Mp \Delta t] \end{aligned}$$

Taking the limit of both sides of this expression as the time interval Δt approaches zero yields the rate of change in the number of undetected problem,

$$\frac{dP_n(t)}{dt}.$$

$$\frac{dP_n(t)}{dt} = \lim_{\Delta t \rightarrow 0} \frac{P_n(t+\Delta t) - P_n(t)}{\Delta t} =$$

$$\lambda P_{n-1}(t) - (\lambda + Mp)P_n(t) + (n+1)MpP_{n+1}(t)$$

The fewest possible number of undetected problems is zero so $P_{-1}(t) = 0$ for all t . At $n=0$ then

$$\frac{dP_0(t)}{dt} = (\lambda+0)P_0(t) + MpP_1(t)$$

$$\frac{dP_0(t)}{dt} = -\lambda P_0(t) + MpP_1(t)$$

For purposes of this study, the steady state or long term average number of undetected problems is of interest. In this steady state situation $\frac{dP_n(t)}{dt} = 0$ or equivalently $P_n(t)$ is a constant for all values of n over all time.

$$\frac{dP_0(t)}{dt} = 0 = -\lambda P_0 + MpP_1$$

$$\text{or } P_1 = \frac{\lambda}{Mp} P_0$$

where the time arguments, no longer needed, have been omitted.

Setting $\frac{dP_1(t)}{dt} = 0$ and substituting

for P_1 yields

$$P_2 = \frac{1}{2} \left(\frac{\lambda}{Mp} \right)^2 P_0$$

Continuing in this fashion yields the general expression

$$P_n = \begin{cases} \frac{1}{n!} \left(\frac{\lambda}{Mp} \right)^n P_0 & \text{for } n \leq s \\ 0 & \text{otherwise} \end{cases}$$

The sum of the steady state probabilities of having all possible numbers of undetected problems must be unity. Therefore,

$$\sum_{n=0}^{\infty} P_n = 1 = P_0 \sum_{n=0}^{\infty} \frac{1}{n!} \left(\frac{\lambda}{M_p} \right)^n$$

The summation on the right is the series expression for the exponential e^{λ/M_p} .

$$1 = P_0 e^{\lambda/M_p} \quad \text{or}$$

$$P_0 = e^{-\lambda/M_p}$$

Substituting this into the general expression for P_n yields

$$P_n = \frac{1}{n!} \left(\frac{\lambda}{M_p} \right)^n e^{-\lambda/M_p}$$

Substituting for P_n and factoring $\frac{\lambda}{M_p} e^{-\lambda/M_p}$

outside the summation yields

$$\bar{n} = \frac{\lambda}{M_p} e^{-\lambda/M_p} \sum_{n=1}^{\infty} \frac{1}{(n-1)!} \left(\frac{\lambda}{M_p} \right)^{n-1}$$

Substituting $k = n-1$, the expected number of undetected problems is

$$\bar{n} = \frac{\lambda}{M_p} e^{-\lambda/M_p} \sum_{k=0}^{\infty} \frac{1}{k!} \left(\frac{\lambda}{M_p} \right)^k$$

The summation on the right is again the exponential e^{λ/M_p}

$$\bar{n} = \frac{\lambda}{M_p} e^{-\lambda/M_p} e^{\lambda/M_p} = \frac{\lambda}{M_p}$$

Since problems are arising at an average rate λ , the average life span of an undetected problem is

$$L = \frac{\bar{n}}{\lambda} = \frac{1}{M_p}$$

Applying the Expression

For a specified monitoring/detection system, the number of inspectors, M, is known and p can be estimated. For example, given a well defined area, assume 3 inspectors are assigned the responsibility to detect problems so M=3. Assume that each month a man can thoroughly inspect 50% of the entire area for which he is responsible. Assume further that if a problem exists at a site when inspected, it will be detected with probability 1. So $p = 0.5/\text{inspector/month}$ and

$$L = \frac{1}{Mp} = \frac{1}{(3\text{MEN})(.5/\text{MAN/MONTH})} = \frac{\text{MONTH}}{1.5} = \frac{2}{3} \text{ MONTH or 20 days}$$

With LANDSAT data, assume a detection system can scan this entire area once every 10 days, and the probability of all conditions (cloud cover, etc) being conducive to a good LANDSAT reading is 0.7.

Here M=1, $p=.7/10$ days and the average length of time a problem will go undetected is

$$L = \frac{1}{.7/10 \text{ days}} = \frac{10 \text{ days}}{.7} = 14.3 \text{ days}$$

The monitoring benefits derived from the LANDSAT data is the reduced life of problems $(20-14.3) = 5.7$ day shorter life of problems. Alternatively this could be expressed as fewer undetected problems at any point in time. Using the example figures:

Status Quo.	$\bar{n} = 20\lambda$
With LANDSAT	$\bar{n} = 14.3\lambda$

where λ is the problem arrival rate expressed in problems/day.

LANDSAT has allowed the expected number of undetected problems to be reduced by $(\frac{20-14.3}{20}) 100 = 28.5\%$.

Valuing the Monitoring Benefits Derived From LANDSAT

The system's better detection rate may deter some violations. A conservative assumption though would be that problem arrivals are independent of the detection rate. The benefits from LANDSAT then can be summarized in the 5.7 day reduction in problem life. If the damage/day can be estimated in dollar terms or in fish killed or soil eroded or some other measurable terms, the monitoring benefits can be similarly quantified. For example,

$$B_{\text{LANDSAT}} = \frac{5.7 \text{ days}}{\text{problem}} (\$600 \text{ damage/day}) (1 \text{ problem/10 days}) = \$342/\text{day}$$

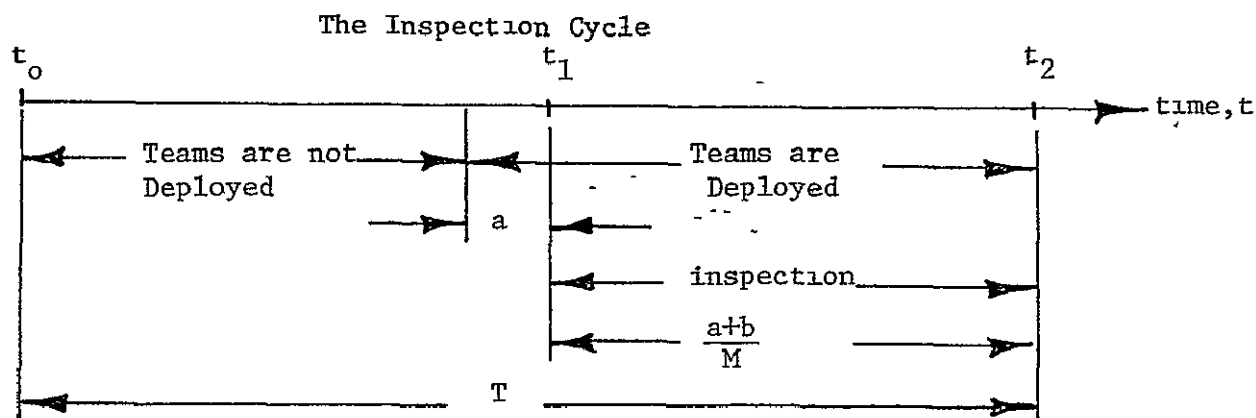
$$\text{or } B_{\text{LANDSAT}} = \frac{\$342}{\text{Day}} \left(\frac{365 \text{ days}}{\text{year}} \right) = \$124,830/\text{year}.$$

where problems have been assumed to arise at an average rate of one per 10 days ($\lambda = 0.1$)

A second type of monitoring or inspection or enforcement which is conducted by state agencies is site-specific inspection. To model this, two assumptions are made. First, is a fixed period of inspection. That is, the time between visits between any given site is essentially constant. Second assumption is that the occurrence of problems is unaffected by the mode of detection or equivalently by a type of inspection. That is to say there are no deterrent effects operating to influence the occurrence of problems or violations at a site. A queuing model can also be used to model site-specific enforcement activities. Such a queuing model differs slightly from the one seen earlier as follows. First, it is based on a finite source, i.e., the number of permitted activities at any point in time is fixed. These are the locales among which all permit violations or problems are confined. A second feature of the present queuing model is that the violations or problems occur at random points in time. This is effectively the assumption of the negative exponential distribution is appropriate to characterize the interarrival times of problems.

A stochastic que discipline is assumed. That is, the detection process associated with site-inspection is assumed to be probabilistic in nature. The output of interest in using the queuing model is the waiting time in queue. This corresponds as noted earlier to the average length of time a problem goes undetected in the field. Any decrease in the length of time a problem goes undetected is taken as a measure of benefits derived from using Landsat data. The decrease in the length of undetected problems life is assumed to reflect a measure of the averted damage on assumption.

Assume in a given area, a set of S sites exist at which permitted activities are conducted. These sites are to be periodically inspected to assure that the activities are in accordance with established regulations. A general model of the inspection process can be given as follows. M inspection teams are deployed periodically to inspect the set of S sites $M \leq S$. An average inspection period T gives the time between successive inspections of any site. Let a denote the average intersite transit time and b the average time it actually takes to perform an inspection once a team is on-site. Let n denote the number of sites at which undetected violations exist $n \leq S$. In general the inspection process can be shown as distinct activities on a time axis:



The probability that a site contains a violation is n/S . Detection of a problem will occur when a site containing a violation is inspected by some one of the inspection teams. Let Δt be a small interval of time such that $\Delta t < a+b$, the average time needed to travel to and inspect one site. Consider any Δt beginning at time t in the period $t_1 \leq t \leq t_2 - \Delta t$. An expression can be developed for the probability that a particular site will be inspected during Δt . The proportion of the time sites actually being inspected is $b/(a+b)$; the proportion of the sites which are subject to being inspected in the next Δt time units is M/S . Combining these, the probability of a single violation being detected in the interval Δt ,

$$\left(\frac{1 \text{ site}}{\text{Team U.T.}} \right) M \text{ TEAMS} = M \frac{\text{Sites}}{\text{U.T.}}$$

$$P(D=1 | t_1 \leq t < t_2 - \Delta t), \text{ is } P(\text{A Site Has A Violation}) \cdot P(\text{Such A Site Is Inspected}), \text{ or}$$

$$P(D=1 | t_1 \leq t < t_2 - \Delta t) = \frac{n}{S} \frac{b}{(a+b)} \frac{M}{S} \Delta t = \frac{Mnb}{S^2(a+b)} \Delta t$$

If $t_0 \leq t < t_1 - \Delta t$, no inspection teams are deployed, and $P(D=1 | t_0 \leq t < t_1 - \Delta t) = 0$

For an arbitrary point in the inspection cycle $t_0 \leq t < t_2 - \Delta t$, the probability of a single detection in the next Δt time units is

$$P(D=1) = P(D=1 | t_1 \leq t < t_2 - \Delta t) P(t_1 \leq t < t_2 - \Delta t) +$$

$$P(D=1 | t_0 \leq t < t_1 - \Delta t) P(t_0 \leq t < t_1 - \Delta t)$$

In the limit as Δt approaches zero

$$P(t_1 \leq t < t_2 - \Delta t) = (a+b)S/MT \text{ and}$$

$$P(t_0 \leq t < t_1 - \Delta t) = 1 - (a+b)S/MT$$

Substituting these into the expression for $P(D=1)$ yields

$$P(D=1) = \frac{Mnb}{S^2(a+b)} \Delta t \frac{(a+b)S}{MT} = \frac{nb}{ST} \Delta t,$$

the probability of a single violation being detected in a small interval of time Δt . As might have been anticipated, the probability of a single violation being detected in an arbitrary interval $[t, t+\Delta t]$ is independent of the number

of inspection teams. If M is large, inspection will take place only during a small part of the inspection period T . If M is small, inspection spans a larger portion of T . In either case the time spent actually inspecting sites is the same, Sb ; it is merely distributed over T differently depending upon M .

Define the arrival of violation as a violation arising at a site where no violation previously existed. A second undetected violation at a site can be interpreted as an expansion of the original violation. If λ is the average rate at which violations arise at any one site, the average arrival rate of violations for the set of S sites is proportional to the number of violation-free sites, $(S-n)$. Define λ_n as the average arrival rate of violations when n of the S sites already contain violations.

$$\lambda_n = (S-n)\lambda$$

The probability of a violation occurring in any short time interval Δt , $P(A=1)$, is

$$P(A=1) = \lambda_n \Delta t = (S-n)\lambda \Delta t$$

Define an event as either a violation arising or a violation being detected. Let the time interval Δt be small enough so that the probability of two or more events occurring during Δt is negligible small. Eventually Δt is to approach zero in the model, so this requirement does not constitute a restrictive assumption. With this assumption, the probabilities of the possible changes in the status of the S sites in a time interval Δt can be written. Let $P_n(t)$ be the probability of having exactly n undetected violations at time t . The probability of having n undetected violations at time $t + \Delta t$ is

$$P_n(t+\Delta t) = P_{n-1}(t)p_{+1} + P_n(t)p_0 + P_{n+1}(t)p_{-1}$$

where p_{+1} , p_0 and p_{-1} are the probabilities of the number of undetected violations increasing by one, remaining unchanged and decreasing by one respectively. p_{+1} , the probability of going from $n-1$ to n undetected violations, is the probability of one arrival and no detections during Δt .

$$p_{+1} = [S-(n-1)] \lambda \Delta t [1-(n-1)b \Delta t/ST]$$

p_0 , the probability of remaining with n undetected violations, in the probability of no arrivals and no detections during Δt .

$$p_0 = [1-(S-n)\lambda \Delta t][1-nb\Delta t/ST]$$

p_{-1} ; the probability of going from $n+1$ to n undetected violations, is the probability of no arrivals and one detection during Δt .

$$p_{-1} = 1-[S-(n+1)]\lambda \Delta t[(n+1)b\Delta t/ST]$$

Substituting these into the expression for $p_n(t+\Delta t)$:

$$p_{-1} = 1-[S-(n+1)] \lambda \Delta t [(n+1)b\Delta t/ST]$$

Substituting these into the expression for $p_n(t+\Delta t)$:

$$\begin{aligned} p_n(t+\Delta t) &= p_{n-1}(t) [S-(n-1)] \lambda [1-(n-1)b\Delta t/ST] \Delta t \\ &+ p_n(t) - p_n(t) [\lambda (S-n) + nb/ST - (S-n) \lambda nb\Delta t/ST] \Delta t \\ &+ p_{n+1}(t) \{1-[S-(n+1)\lambda \Delta t][(n+1)b/ST]\} \Delta t \end{aligned}$$

Rearranging terms

$$\frac{p_n(t+\Delta t) - p_n(t)}{\Delta t} =$$

$$\begin{aligned} &p_{n-1}(t) [S-(n-1)] \lambda [1-(n-1)b\Delta t/ST] \\ &- p_n(t) [\lambda (S-n) + nb/ST - (S-n) \lambda nb\Delta t/ST] \\ &+ p_{n+1}(t) \{1-[S-(n+1)\lambda \Delta t][(n+1)b/ST]\} \end{aligned}$$

The rate of change in the number of undetected violations, $\frac{dP_n(t)}{dt}$, is found by taking the limit of the above expression as Δt approaches zero.

$$\begin{aligned} \frac{dP_n(t)}{dt} = \lim_{\Delta t \rightarrow 0} \frac{P_n(t+\Delta t) - P_n(t)}{\Delta t} = \\ P_{n-1}(t) [\lambda(S-n+1)] \\ - P_n(t) [\lambda(S-n) + nb/T] \\ + P_{n+1}(t) [(n+1)b/T] \end{aligned}$$

Since the minimum number of undetected violations is zero $P_{-1}(t) = 0$ for all t .

So at $n=0$

$$\frac{dP_0(t)}{dt} = 0 - P_0(t) [\lambda S] + P_1(t) [b/T]$$

Similarly, since the maximum number of undetected violations is S , $P_{S+1}(t) = 0$ for all t .

So at $n=S$

$$\frac{dP_S(t)}{dt} = P_{S-1}(t) [\lambda] - P_S(t) \left[\frac{b}{T}\right]$$

Define the steady state as that condition in which no period to period change in the number of undetected violations takes place. This steady state condition can be described in terms of the average state of the S sites over time. Noting that the steady state condition addresses the average condition within an inspection period, information about the average state of the S sites can be developed. In the steady state,

$\frac{dP_n(t)}{dt} = 0$ for all n , or equivalently $P_n(t)$ is a constant where $P_n(t)$ is interpreted as the probability of having an average of n undetected violations over an inspection period. Omitting the no longer need time arguments on

$P_n(t)$,

Setting $\frac{dP_0}{dt} = 0 = -\lambda S P_0 + b P_1 / ST$ or

$$P_1 = [\lambda ST / b] P_0$$

Setting $\frac{dP_1}{dt} = 0 = \lambda P_0 - [\lambda(S-1)+b/ST]P_1 + 2bP_2/ST$

Substituting for $P_0 = bP_1 / S^2 P_0$ yields

$$P_2 = [\lambda ST/b](S-1)P_1/2$$

Continuing in this fashion yields the general recursive expression

$$P_n = [\lambda ST/b](S-n+1)P_{n-1}/n$$

A more convenient form of this is obtained by expressing P_n in terms of P_0 .

$$P_0 = P_n$$

$$P_1 = [\lambda ST/b]SP_0$$

$$P_2 = [\lambda ST/b](S-1)P_1/2 = [\lambda ST/b]^2(S)(S-1)P_0/2$$

$$P_3 = [\lambda ST/b](S-2)P_2/3 = [\lambda ST/b]^3(S)(S-1)(S-2)P_0/6$$

or in general

$$P_n = (\lambda ST/b)^n \frac{S!}{(S-n)!n!} P_0$$

It must be the case that the sum of the probabilities of having all possible average numbers of undetected violations is one.

$$\sum_{n=0}^S P_n = 1 = P_0 \sum_{n=0}^S \left(\frac{\lambda ST}{b}\right)^n \frac{S!}{(S-n)!n!}$$

The summation on the right hand side is the binomial expansion of $(1+\lambda ST/b)^S$.
Substituting and solving for P_0 yields

$$P_0 = (1+\lambda ST/b)^{-S}$$

Substituting this in the expression for P_n yields

$$P_n = (\lambda ST/b)^n \frac{S!}{(S-n)!n!} (1+\lambda ST/b)^{-S}$$

To find the average length of time a violation goes undetected, it is necessary to first find the expected number of undetected violations,

$$\bar{n} = \sum_{n=0}^S n P_n$$

$$\bar{n} = (1+\lambda ST/b)^{-S} \sum_{n=0}^S \frac{nS!}{(S-n)!n!} \left(\frac{\lambda ST}{b}\right)^n$$

The first term in the summation is zero, therefore

$$\bar{n} = (1+\lambda ST/b)^{-S} \sum_{n=1}^S \frac{S!}{(S-n)!(n-1)!} \left(\frac{\lambda ST}{b}\right)^n$$

Let $k = n-1$. Using this new index and factoring $S(\lambda ST/b)$ outside the summation yields

$$\bar{n} = (1+\lambda ST/b)^{-S} (\lambda S^2 T/b) \sum_{k=0}^{S-1} \frac{(S-1)!}{[(S-1)-k]!k!} \left(\frac{\lambda ST}{b}\right)^k$$

The summation on the right is the binomial expression of $(1+\lambda ST/b)^{S-1}$.

Substituting

$$\bar{n} = (1+\lambda ST/b)^{-S} (\lambda S^2 T/b) (1+\lambda ST/b)^{S-1}$$

$$\bar{n} = \lambda S^2 T/b (1+\lambda ST/b) \text{ or}$$

$$\bar{n} = \lambda S^2 T/(b+\lambda ST)$$

The average length of time a violation goes undetected is $L=\bar{n}/\lambda$

$$L=S^2 T/(b+\lambda ST)$$

It should be noted that $b \ll \lambda ST$

Then

$$L = \frac{S^2 T}{\lambda ST} = \frac{S}{\lambda} \text{ as would be expected.}$$

These models of the benefits derived from using Landsat Data Systems are intended to be general characterizations of the operational improvements that will be realized. The models above should be perceived as one way of describing first order benefits derived from Landsat Data System. On gaining some experience with the Landsat data products the necessary input to the model or estimates of the inputs should be obtainable. At this point, the quantification of the benefits will be meaningful and the state agencies and NASA will be better able to state the magnitude of the physical advantages derived from Landsat data.

APPENDIX IV

CBA COMPUTER PROGRAM AND NOMINAL CASE INPUTS

- A. Description of Input File
- B. Flowchart for CBA/NPV Program
- C. CBA Program Listing

A. DESCRIPTION OF INPUT FILES

Input variables are listed in order as read by the program; all data is in free-field format.

All cost factors cited were escalated at 8% per annum to reflect 1977 costs.

The computer program projects future costs in terms of 1977 dollars, i.e., cost values remain constant; the program's output is Net Present Value of the Landsat Data System, the discount rate, and the final year for which costs were calculated.

1. INPUT FILE "5" -- CONTROL VARIABLES AND NOMINAL VALUES

VARIABLES READ	DESCRIPTION
H,Q,D,AREA,NDP	H = horizon time (1985, H=9)
9,4,0.07,59000.,5	Q = # times per year information is to be updated
	D = discount rate
	AREA = area (59,000 sq. miles for State of Georgia)
	NPD = number of data products obtainable
I, NSP(I,J)	NSP(I,J) = No. sets of satellite-derived product
1,7,7,7,7	I at time J; I=1,2,...,NDP, J=1,2,...,Q
2,0,0,0,0	I = 1, summary statistics
3,0,0,0,0	I = 2, printer plotter map
4,0,0,0,0	I = 3, dummy product
5,7,7,7,7	I = 4, digitized data
	I = 5, color classified mosaic negative
I, NAP(I,J)	NAP(I,J) = No. sets of alternative-derived product
1,7,7,7,7	I at time J, I=1,2,...,NDP, J=1,2,...,Q
2,0,0,0,0	I = 1, summary statistics
3,0,0,0,0	I = 2, printer plotter map
4,0,0,0,0	I = 3, orthophoto map
5,7,7,7,7	I = 4, digitized data
	I = 5, non-georeferenced color mosaic negative

Notes: The values for Q, NSP(I,J), and NAP(I,J) are based on the user survey.

The computer program sets NSP(4,J) and NAP(4,J) to 1 at a time corresponding to 1981

2. INPUT FILE "3" -- LDS COST FACTORS AND NOMINAL VALUES

VARIABLES READ	DESCRIPTION
NSCNS, CPSCN, SADMIN, SINVEST, SSET	NSCNS = No. scenes per coverage CPSCN = Cost per scene SADMIN = Annual administrative maintenance and overhead cost SINVEST = investment to design, acquire, and install ERDAS (sunk) SSET = set-up cost to process any amount of data on ERDAS
14,200.,35000.,115000.,555	
[S1PC(I), I=1, NDP]	S1PC(I) = Satellite Product I, per sq. mile first cost, i.e. excludes reproduction
0.00,0.00,0.00,0.00,0.15	
[SPRC(I), I=1, NDP]	SPRC(I) = Satellite product I, per copy reproduction cost
0.00,0.00,0.00,200.,175.	
SGREF(K,L), K=1,2 L=1,Q]	SGREF = Georeferencing cost per sq. mile in year K, period L [this format can pro- vide for a "learning effect," or decreasing unit cost, if desired]
0.30,0.30,0.30,0.30	
0.30,0.30,0.30,0.30	
[STS(K,L), K=1,2, L=1,Q]	STS = Training sample cost per sq. mile in year K, period L [provides a decreasing unit cost if desired]
0.30,0.26,0.22,0.18	
0.14,0.10,0.06,0.06	
[SCLAS(K,L), K=1,2, L=1,Q]	SCLAS = Classification cost per sq. mile in year K, period L [provides a decreasing unit cost if desired]
0.10,0.10,0.10,0.10	
0.10,0.10,0.10,0.10	

Notes: All values are based on actual and anticipated costs to the State of Georgia, as incurred at Ga. Tech.

The data processing cost values are those being experienced by the ERDAS operators. STS(K,L) include interaction with field personnel for the ground truth effort, which gradually decreases to 20% of its initial value; this "leveling out" reflects the fact that as land cover changes, some old training samples will need to be validated and some new ones selected. SGREF(K,L) is expected to remain relatively high as georeferencing requires a high degree of man-machine interaction. SCLAS(K,L) is based upon an average of two classification runs per scene; the ERDAS personnel have found that one classification run is generally adequate.

S1PC(I) and SRPC(I) are based on the experience of the ERDAS operators. The [0.00] values are, in actuality, either negligible or accounted for in other cost factors; e.g. statistics are tallied during classification runs. SRPC(5) is based on a commercial quote.

If SINVEST were not sunk it would be treated as an LDS cost incurred at time zero.

3. INPUT FILE "4" -- BAEEDS COST FACTORS AND NOMINAL VALUES

VARIABLES READ	DESCRIPTION
ACP,AADMIN,AINVEST 4.00,25000.,0.	ACP = Cost per sq. mile photographed AADMIN = Annual program administration cost AINVEST = cost to develop, organize, and implement the program
[AIPC(I), I=1, NDP] 0.60,0.00,3.32,3.75,0.50	AIPC(I) = Alternative product I, per sq. mile first cost; excludes reproduction
[ARPC(I), I=1, NDP] 0.00,0.00,175,200,175	ARPC(I) = Alternative Product I, per copy reproduction cost
[AFW(J), J=1,Q] 4.42, 4.42, 4.42, 4.42	AFW(J) = Cost per sq. mile to perform field work in period J
[AFWA(J), J=1,Q] 0.,0.,0.,0	AFWA(J) = Field work area in sq. mile to be sampled/inspected in period J

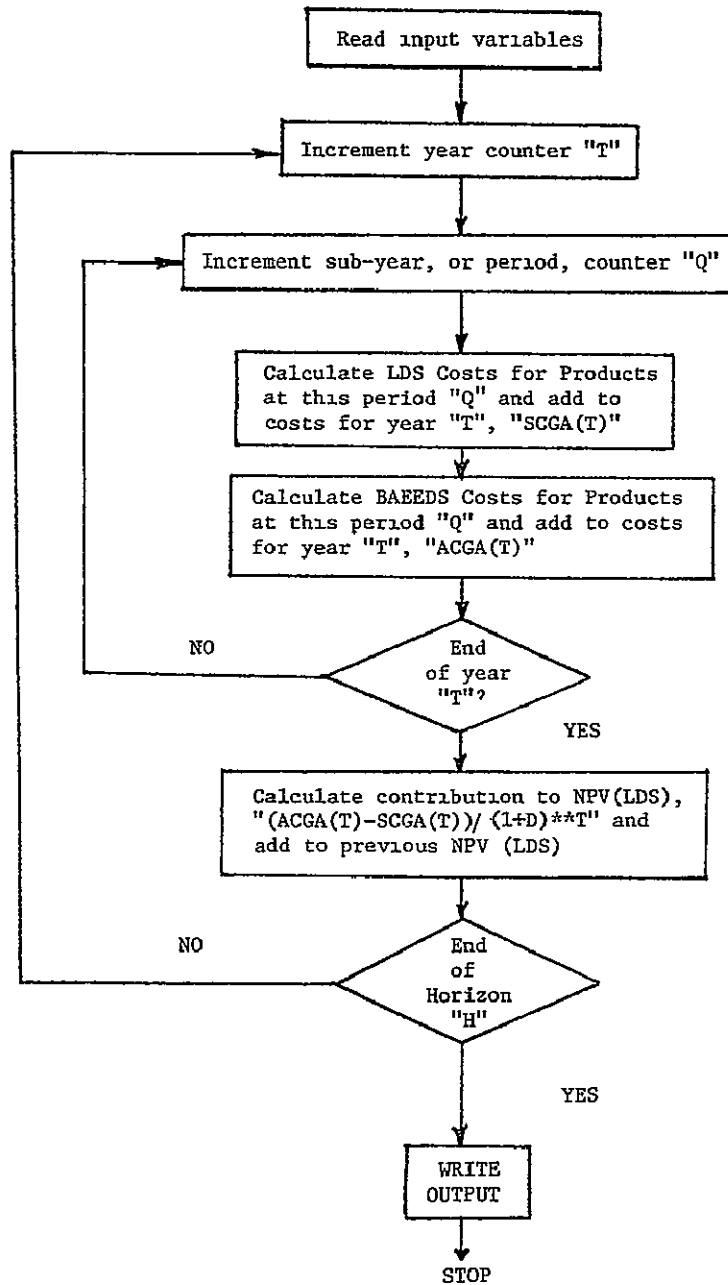
Notes: The ACP value includes flight cost, photo indexing, and one set of color infrared negatives and contact prints at a scale of 1:63360 (1"=1 mile). A range of \$3-5/Sq. mi. is given in a Bendix report by Rogers, et. al. The value and its range are further supported by derivations of cost factors according to the scale, overlap, terrain, and other relationships described in the Manual of Remote Sensing.

AINVEST is assumed to be negligible, otherwise it would be treated as a BAEEDS cost incurred at time zero.

AIPC(I) and ARPC(I) are estimates based on Remote Sensing of Earth Resources, Vol IV, correspondence with Dr. James R. Anderson of the USGS LUDA project, the Manual of Remote Sensing, and quotes from Moderna Photo Lab, Inc.

AFW(J) is an average of estimates cited in the ECON, Inc. Study NASW-2558 December 1974 and Satellite Corp/Booz Allen Contract #135-19, USGS November 1974.

B FLOWCHART FOR CBA/NPV PROGRAM



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C ENTER LANDSAT COST MODULE

C

```

      DO 888 T=1,H
      SCGA(T)=0.0
      ACGA(T)=0.0
      DO 777 N=1,Q
      IF (T.GE. 5) NSF(4,N)=1
      IF (T.GE. 5) NAF(4,N)=1
      SIFC=0.0
      ATIC=0.0
      ACPIX=0.0
      IF (NSF(1,N).LT.1) GO TO 770
      SCDAT=NSCNS*CFSC(N)
      SCFF=AREA*(SGREF(T,N)+STS(T,N)+SCLAS(1,N)) *SSET
      DO 66 J=1,NDF
      SFTC(J)=0.0
      IF (NSF(J,N).GT.0) SFTC(J)=SIFC(J)*AREA*NSF(J,N)*SGFLC(J)
      STFC=STFC+SFTC(J)
66  CONTINUE
      GO TO 775
770  SCDAT=0.0
      SCIF=0.0
775  SCGA(T)=SCGA(T)+SCDAT+SCFF+STFC

```

C

C

ENTER BASED'S COST MODULE

C

```

      ACFW=AFW(N)*AFWA(N)
      IF (NAF(1,N).LT.1) GO TO 880
      ACPIX=ACF*AREA
      DO 67 J=1,NDF
      AFTC(J)=0.0
      IF (NAF(J,N).GT.0) AFTC(J)=AIFC(J)*AFGA*NAF(J,N)*ARFC(J)
      AIFC=AIFC+AFTC(J)
67  CONTINUE
      GO TO 885
880  AFTC=0.0
885  ACGA(T)=ACGA(T)+ACFW+AFTC+ACPIX
777  CONTINUE
      SCGA(T)=SCGA(T)+SADMIN
      ACGA(T)=ACGA(T)+AADMIN
      BENILS(T)=(ACGA(T)-SCGA(T))/(1.+D)*I
      FVN=FVN+BENILS(T)
888  CONTINUE

```

C

C

OUTPUT MAKING

C

```

      NYR=1976111
      WRITE(6,10)SCGA(1),SCGA(2),SCGA(3),SCGA(7),ALGA(1),ACGA(3),ALGA(7)
      WRITE(6,11) NYR,FVN
10  FORMAT(10X,"FIRST YEAR TOTAL LANDSAT/ERDAS COST IS ",F10.0,/,
11X,"SECOND YEAR TOTAL LANDSAT/ERDAS COST IS ",F10.0,/,
21X,"THIRD YEAR TOTAL LANDSAT/ERDAS COST IS ",F10.0,/,
31X,"SEVENTH YEAR TOTAL LANDSAT/ERDAS COST IS ",F10.0,/,
41X,"FIRST YEAR ALTERNATIVE COST IS ",F10.0,/,
51X,"THIRD YEAR ALTERNATIVE COST IS ",F10.0,/,
61X,"SEVENTH YEAR ALTERNATIVE COST IS ",F10.0,/,)
11  FORMAT(5X,"THESE COSTS WERE ANALYZED IN TERMS OF THE NET PRESENT ",
17X,"VALUE CRITERION USING A DISCOUNT RATE OF ",F4.2," PERCENT",/,
25X," AND FOR A TIME HORIZON OF ",F5.2,/,
35X," AND YIELDS A NET PRESENT VALUE FOR THE PROJECT OF ",F10.0)
      STOP

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C CBA PROGRAM LISTING

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PROGRAM CBA(INFUT,OUTFUT,TAPE3,TAPE4,TAPE5,INFUT,TAPE6=OUTFUT)
DIMENSION S1FL(10),SRFC(10),A1FL(10),ARFC(10),SFIL(10),AFIL(10)
DIMENSION NSF(10,5),NAF(10,5)
DIMENSION PENICS(20),SCGA(20),ACGA(20)
DIMENSION SGRF(20,5),STS(20,5),SCLAS(20,5)
DIMENSION AFW(5),AFWA(5)
INTEGER T,Q,II

C
C READ IN CCA CONTROL VARIABLES
C
  READ(5,*) H,Q,D,AREA,NDF
  DO 55 I=1,NDF
    READ(5,*) M,(NSF(I,J),J=1,Q)
55 CONTINUE
  DO 56 I=1,NDF
    READ(5,*) N,(NAF(I,J),J=1,Q)
56 CONTINUE

C
C READ IN LUS COST FACTORS
C
  READ(3,*) NSCNS=(FSLN,SADMIN,SINVEST,SGFI)
  READ(3,*) (S1IL(I),I=1,NDF)
  READ(3,*) (SRFC(I),I=1,NDF)
  READ(3,*) (SGREF(1,J),J=1,Q)
  READ(3,*) (SGREF(2,J),J=1,Q)
  READ(3,*) (STS(1,K),K=1,Q)
  READ(3,*) (STS(2,K),K=1,Q)
  READ(3,*) (SCLAS(1,I),I=1,Q)
  READ(3,*) (SCLAS(2,I),I=1,Q)

C
C READ IN BAEEDS COST FACTORS
C
  READ(4,*) ACF,AADMIN,AINVEST
  READ(4,*) (A1FC(J),J=1,NDF)
  READ(4,*) (ARFC(J),J=1,NDF)
  READ(4,*) (AFW(L),L=1,Q)
  READ(4,*) (AFWA(L),L=1,Q)

C
C INITIAL PARAMETER SETTING
C
  IVN=0.0
  DO 65 T=3,II
    DO 65 I=1,Q
      SGREF(T,I)=SGFLF(2,Q)
      STS(T,I)=STS(2,Q)
      SCLAS(T,I)=SCLAS(2,Q)
65 CONTINUE

C
C ENILK LANDSAT COST MODULE

```